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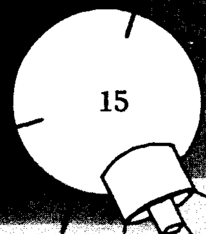

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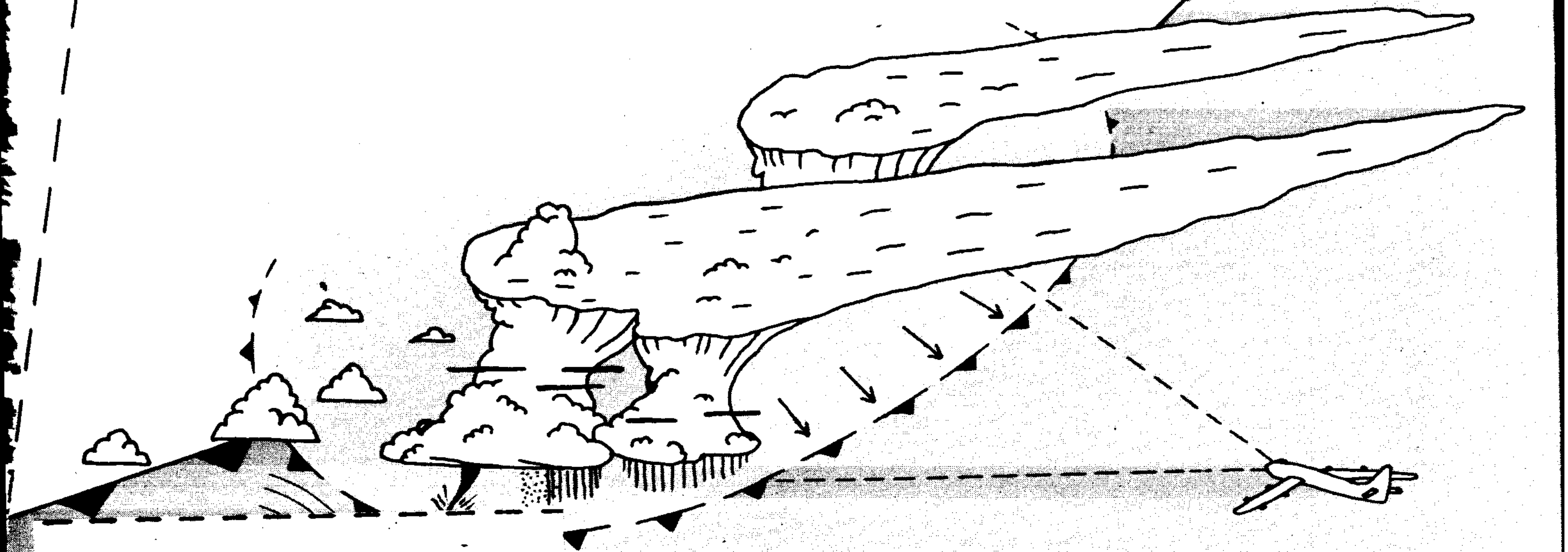
MESOMETEOROLOGY PROJECT

Department of the Geophysical Sciences
The University of Chicago

OUTLINE OF A THEORY AND EXAMPLES FOR PRECISE ANALYSIS OF SATELLITE RADIATION DATA

by
Tetsuya Fujita



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OUTLINE OF A THEORY AND EXAMPLES FOR PRECISE ANALYSIS OF SATELLITE RADIATION DATA*

by
Tetsuya Fujita

The research included in this report has been sponsored by The National Aeronautics and Space Administration under grant NASA NsG 333 and The Meteorological Satellite Laboratory, United States Weather Bureau under grant Cwb WBG-6.

February 1963

*Complete text to follow

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INTRODUCTION AND SUMMARY

Meteorological satellites, TIROS II, III, and IV, obtained a large amount of radiation data with their medium resolution scanning radiometers. These data have been or are being processed into three forms called (1) Grid Print Radiation Map, (2) FMRT Listing, and (3) FMR Tape, and are now available to researchers.

The National Aeronautics and Space Administration published TIROS II RADIATION DATA, Users' Manual and its Supplement; and TIROS III RADIATION DATA, Users' Manual which includes radiation maps from selected TIROS orbits. These are the examples of Grid Print Radiation Maps which may immediately be used for meteorological analysis.

In order to carry out researches on either meteorological or physical interpretation of these radiation data, it is necessary to determine the basic values, (1) the zenith angle and azimuth of the satellite viewed from the scan points on the earth, (2) the areas of scan points on the earth, and (3) the zenith angle and azimuth of the sun viewed from the scan points on the earth. These basic values lead us to investigate further the limb darkening, reflectivity, directional characteristics of radiation and reflection, and numerous other subjects.

The author has developed a method of determining these basic values, precisely yet very quickly, through graphical procedures. The charts, grids, and overlays required for the analysis are listed below.

CHARTS:	Scan Spot Chart (Page 11)
	*Nadir Angle Chart (Page 10)
	Zenith Angle Chart (Page 10)
	Sunglint Point Chart
	Antisolar Point Chart
	*OEC Projection Chart (Fig 44, MSL Rep. 14)
	*TEC Projection Chart (Fig 47, MSL Rep. 14)
OVERLAYS:	*OEC Overlay (Fig 46, MSL Rep. 14)
	*TEC Overlay (Fig 47, MSL Rep. 14)
	Geocentric Angle Overlay (Page 9)
	Azimuth Overlay (Page 9)
GRIDS:	*Tilt Grid (Fig 29, MSL Rep. 14)
	*Height Grid (Fig 50, MSL Rep. 14)
	Radiometer Grid (Page 11)

The items with * are the same ones which are designed for use in the rectification of satellite photographs as reported in MSL Report No. 14. Neither sunglint nor antisolar point charts are included in this report.

It will take some time before a complete text for the method is finished. This report, therefore, has been prepared for use in a workshop or laboratory-type work where additional assistance is available for the users.

I BASIC GEOMETRY

Ia SCAN GEOMETRY

Abbreviations

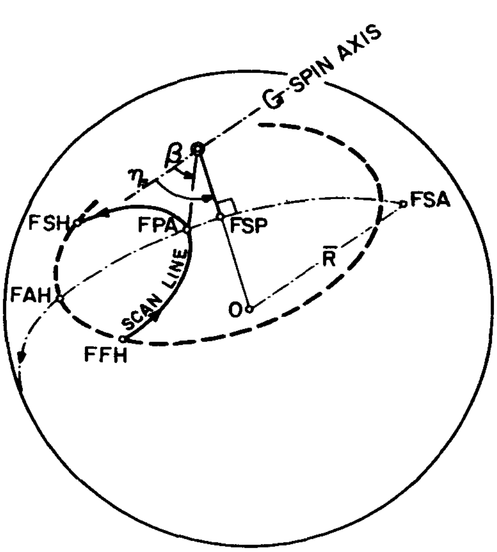
FAA - Fixed-Earth Aponadir
FFH - Fixed-Earth First Horizon
FPA - Fixed-Earth Perinadir
FSH - Fixed-Earth Second Horizon
FSA - Fixed-Earth Spin-Axis Point
FSA' - Fixed-Earth Spin-Axis Antipode
FSC - Fixed-Earth Scan Point
FSP - Fixed-Earth Subsatellite Point
β - inclination of radiometer axis
δ_H - dip angle
η_s - satellite nadir-angle
η_{sc} - scan nadir-angle
η^{FPA} - nadir angle of perinadir

On the fixed-earth coordinates, the spin-axis point (FSA) may be assumed stationary during one orbital period. The primary plane thus rotates around the axis connecting FSA with FSA' as the satellite orbits around the earth.

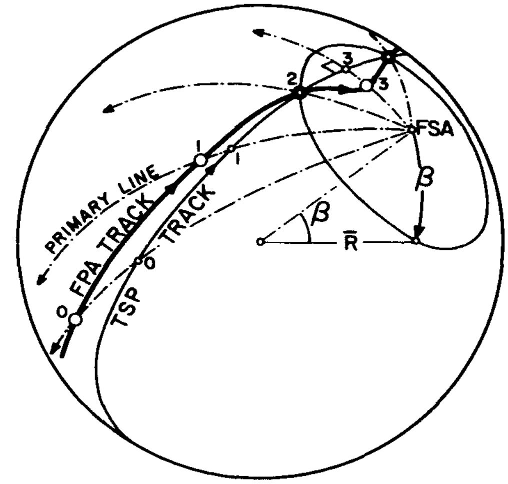
The perinadir is the scan point closest to the subsatellite point during one satellite spin and located on the primary line. The loci of the scan points and the perinadirs are called scan lines and perinadir track, respectively.

At the intersections between the subsatellite point track and the small circle with geocentric angle β from the spin-axis point the perinadir and subsatellite-point tracks cross each other. These intersections are the only points which are scanned by the satellite from directly above. There are two intersections when $\beta > \eta_s^{MIN}$; one intersection when $\beta = \eta_s^{MIN}$; and no intersection when $\beta < \eta_s^{MIN}$.

The radiometer axis intersects the earth if the satellite nadir-angle satisfies the relation $90 - \delta_H > \eta_s - \beta = \eta^{FPA}$. The scan line on the earth is open at the apparent horizon (Open Mode) until η_s decreases to satisfy $90 - \delta_H > \eta_s + \beta = \eta^{FAA}$, for which the scan line on the earth is closed (Closed Mode).



FIXED EARTH



FIXED EARTH

BASIC GEOMETRY

Ib MAP PROJECTION

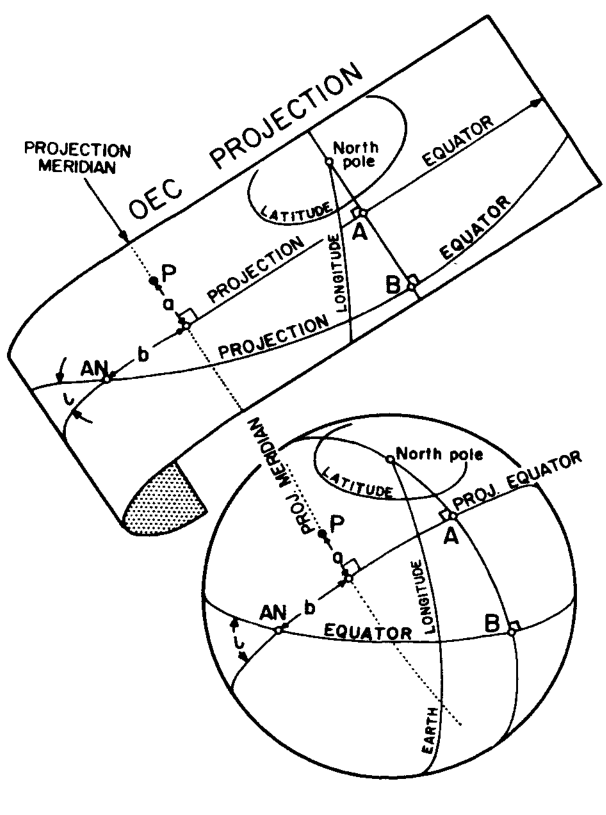
Abbreviations

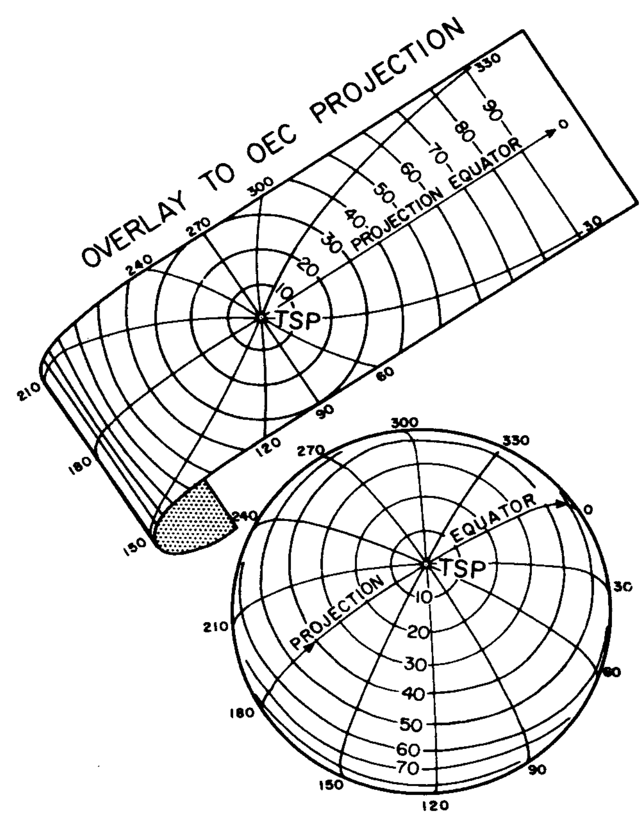
EEC - Equatorial Equidistant Cylindrical Projection
OEC - Oblique Equidistant Cylindrical Projection
TEC - Transverse Equidistant Cylindrical Projection
i - inclination of the projection equator

The OEC projection map with the inclination of the projection equator identical to that of the satellite orbit is conveniently used.

In an OEC projection, the great circle distances along the projection equator and the projection meridians are conserved upon projection. To measure the great circle distance between two arbitrary points, an OEC overlay is required. The overlay is also used in drawing a great circle arc connecting two points on an OEC projection.

The equidistant cylindrical projection with the inclination of 0° and 90° are, respectively, called EEC, and TEC projections. The group of lines on an OEC overlay are identical to those of the TEC projection chart.





BASIC GEOMETRY

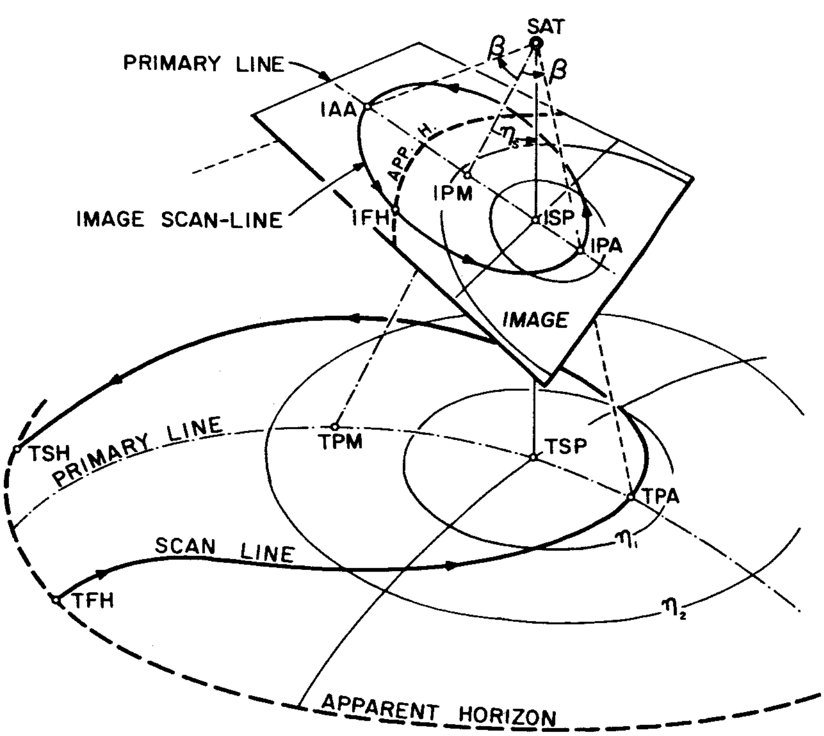
Ic GRID GEOMETRY

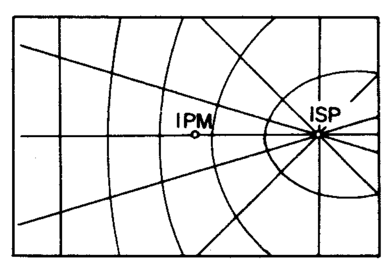
Abbreviations

IAA - Image Aponadir
IPA - Image Perinadir
IPM - Image Primary Point
SAT - Satellite
TFH - Terrestrial First Horizon
TPA - Terrestrial Perinadir
TPM - Terrestrial Primary Point
TSH - Terrestrial Second Horizon
TSP - Terrestrial Subsatellite Point
f - principal distance of tilt grid
β - inclination of radiometer axis
η_s - satellite nadir-angle
η_{sc} - scan nadir-angle

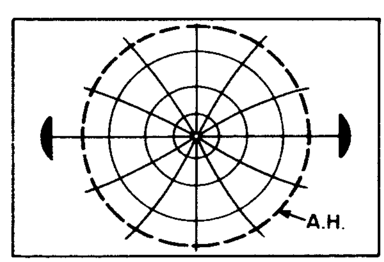
A set of the tilt and height grids, designed to be used in satellite photogrammetry, can also be used in plotting the scan lines on the earth.

A radiometer grid includes the locus of the image scan-point at which the radiometer axis intersects the image plane. The locus is, therefore, a circle with the radius of f tan β centered at IPM. The scan points at 10 degree intervals of the satellite spin angle are sufficient to determine terrestrial scan lines.





TILT GRID



OEC HEIGHT GRID

BASIC GEOMETRY

Id AZIMUTH OVERLAY

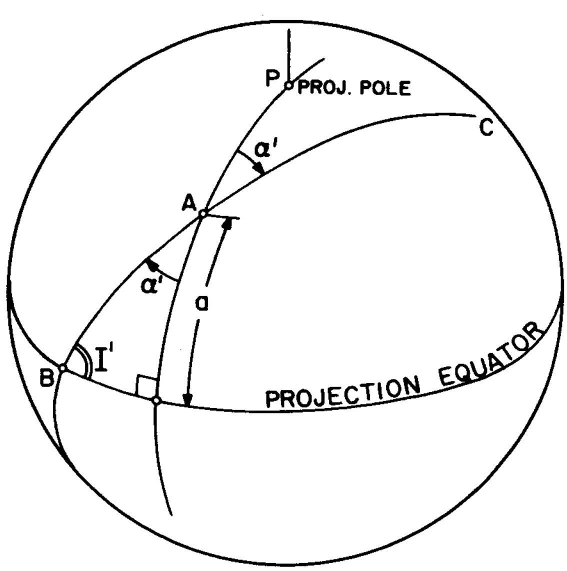
Abbreviations

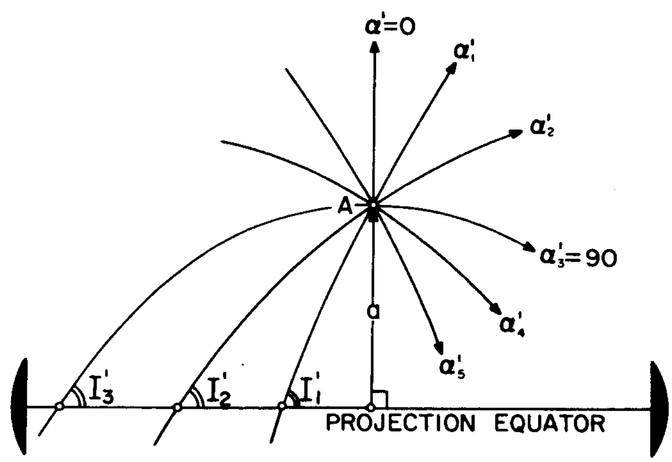
a - great circle distance of point A from the projection equator
α' - azimuth with respect to the projection meridian

An azimuth overlay is designed to perform graphical determination of the azimuth of a great circle passing through a point on an OEC projection chart.

For a given value of a, the great circle distance of the point from the projection equator, the inclination (I') of the great circle BAC in the figure is given by $\cos I' = \sin \alpha' \cos a$. With the use of this equation, the isolines of α' at 10 degree intervals for a = 0, 5, 10, ---- 35 are determined to construct the azimuth overlay.

The azimuth overlay is frequently used in determining the azimuths of the sun and the satellite viewed from any scan point on the earth.





BASIC GEOMETRY

Ie GEOCENTRIC ANGLE OVERLAY

Abbreviations

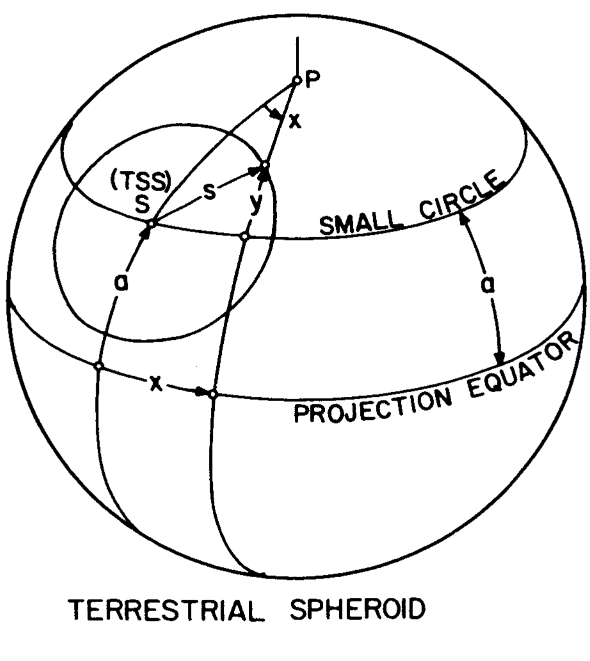
TSS - Terrestrial Subsolar Point
a - geocentric angle of point S from the projection equator in degrees
s - great circle distance between S and a point A on OEC chart in degrees

The geocentric angle overlay is designed to determine the isolines of geocentric angles from a point which is not located on the projection equator. The geocentric angle between the TSS and a point is identical to the zenith angle of the sun.

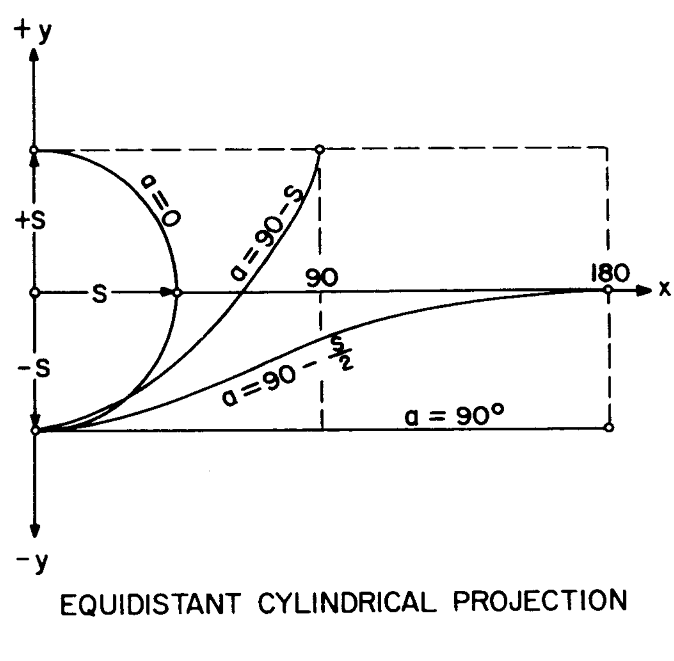
The overlay includes the isolines of geocentric angles for different values of a. The equation of the isolines is given by

$$\cos s = \sin a \sin (a + y) + \cos a \cos (a + y) \cos x.$$

The overlays are available at ten degree intervals of s, so that the isolines can be graphically obtained by tracing the proper curves which vary with a.



TERRESTRIAL SPHEROID



EQUIDISTANT CYLINDRICAL PROJECTION

BASIC GEOMETRY

If NADIR ANGLE AND ZENITH ANGLE CHARTS

Abbreviations

SAT - Satellite
TSP - Terrestrial Subsatellite Point
d - great circle distance from TSP in degrees (subpoint distance)
ζ^{SAT} - zenith angle of satellite
η - nadir angle

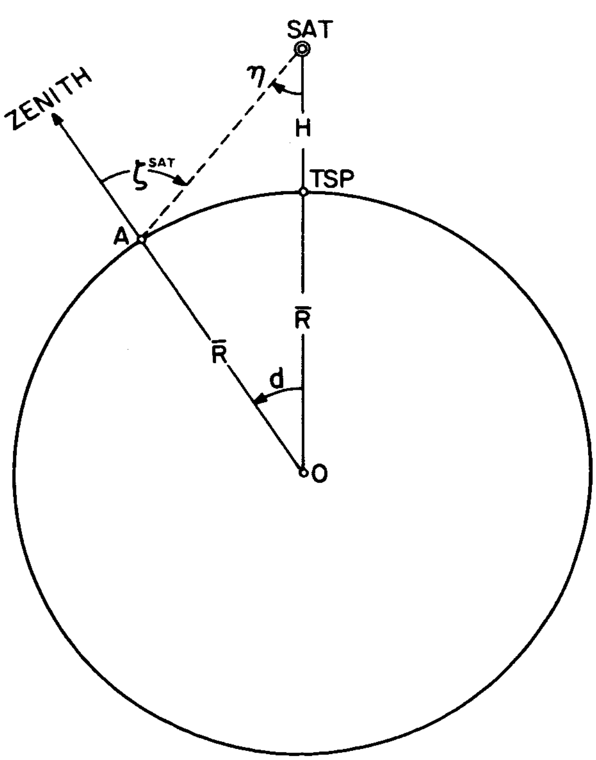
It is frequently required to compute the great circle distance between TSP and a point A on the earth as a function of either the nadir angle or the zenith angle.

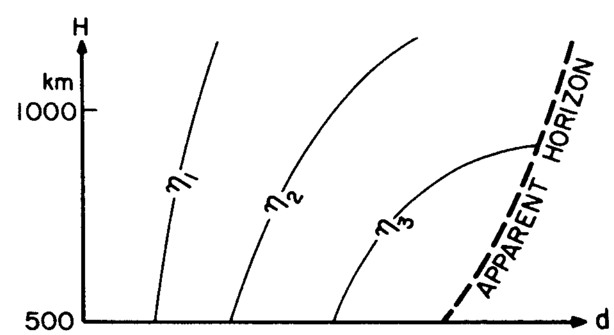
The nadir angle chart includes isolines of the nadir angles computed as a function of satellite height and the great circle distance from TSP. The formula for computation is

$$d = \sin^{-1}\left(\frac{H+R}{R}\sin\eta\right) - \eta .$$

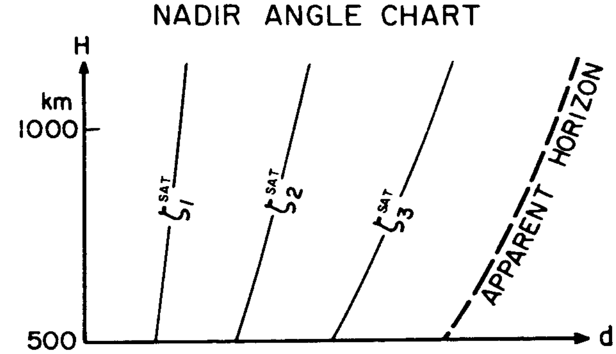
The zenith angle chart consists of the isolines of the zenith angles of satellite viewed from various points away from TSP. The great circle distance from TSP for given zenith angle and the satellite height is

$$d = \zeta^{SAT} - \sin\left(\frac{R}{H+R}\sin\zeta^{SAT}\right).$$





NADIR ANGLE CHART



ZENITH ANGLE CHART

BASIC GEOMETRY

Ig DIMENSIONS OF SCAN SPOTS

Abbreviations

IAA	- Image Aponadir	f	- focal distance of radiometer grid
IPA	- Image Perinadir	β	- inclination of radiometer axis
IPM	- Image Primary Point	$\Delta\beta$	- radial angle from radiometer axis

The radial angles ($\Delta\beta$) of TIROS III radiometers are tabulated as a function of the relative sensitivity in percent.

Relative Sensitivity	100	90	80	70	60	50	40	30	20	10	0	Percent
Channel 1	0.0	1.2	1.5	1.7	2.0	2.3	2.6	3.1	3.7	5.1	8.0	
Channel 2	0.0	1.0	1.3	1.6	1.9	2.2	2.5	2.9	3.3	4.2	7.5	
Channel 3	0.0	0.9	1.2	1.3	1.5	1.7	1.9	2.3	2.6	3.0	5.5	
Channel 4	0.0	1.0	1.4	1.6	1.9	2.2	2.5	2.9	3.4	4.4	8.0	
Channel 5	0.0	0.8	1.1	1.3	1.5	1.8	2.0	2.3	2.6	3.1	6.0	in degrees

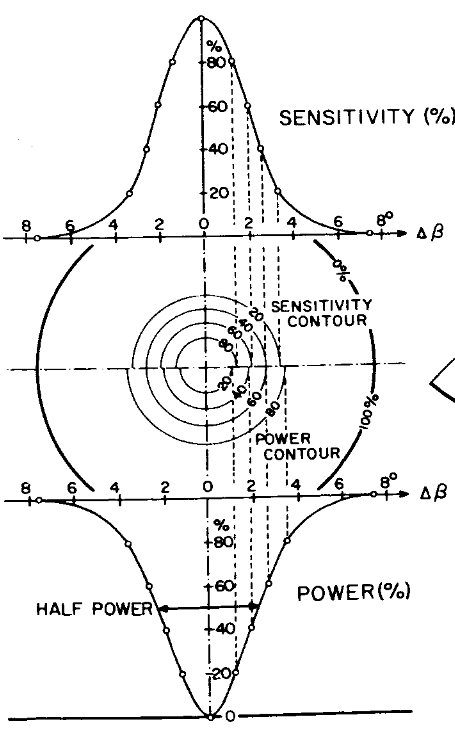
The relative power which is the sensitivity (S) times $\Delta\beta$ integrated out to $\Delta\beta$ from the radiometer axis is given by

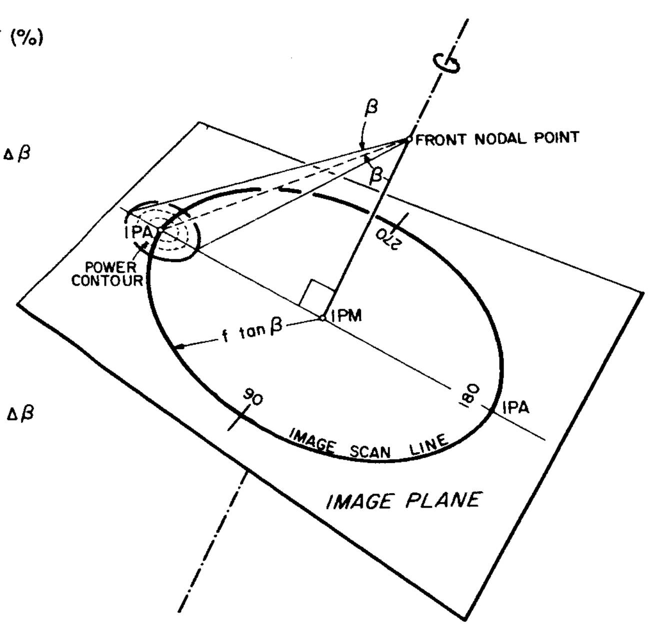
$$P_{\Delta\beta} / P_{8^\circ} = \int_0^{\Delta\beta} S\Delta\beta \, d(\Delta\beta) \Big/ \int_0^{8^\circ} S\Delta\beta \, d(\Delta\beta),$$

where P_{8° is the total power integrated to eight degrees for which the power levels off.

The scan spot, which is the area on the earth surrounded by a specific power contour, is naturally the function of the percent power. The power contours are thus projected on the radiometer grid to permit their transcript onto an OEC chart by using a proper height grid. The 100%-power aperture ($2\Delta\beta$) for TIROS III, channel 2 reaches as much as 15 degrees. The half-power aperture of the same channel was computed to be 4.4 degrees.

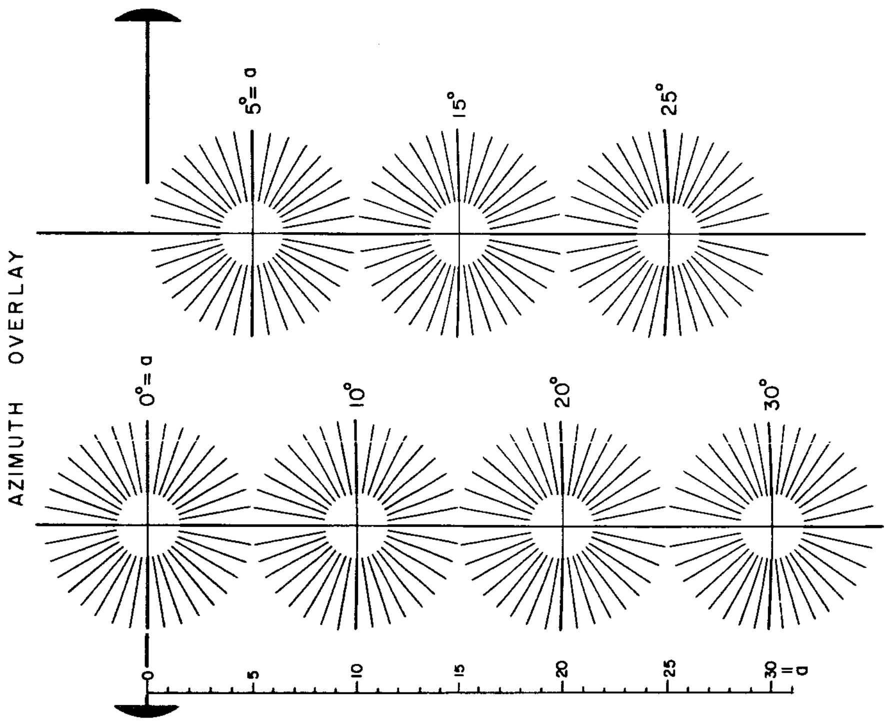
In actual determination of the percent-power spots on an OEC chart, the percent-power scan-spot chart on page 11 is convenient to use.

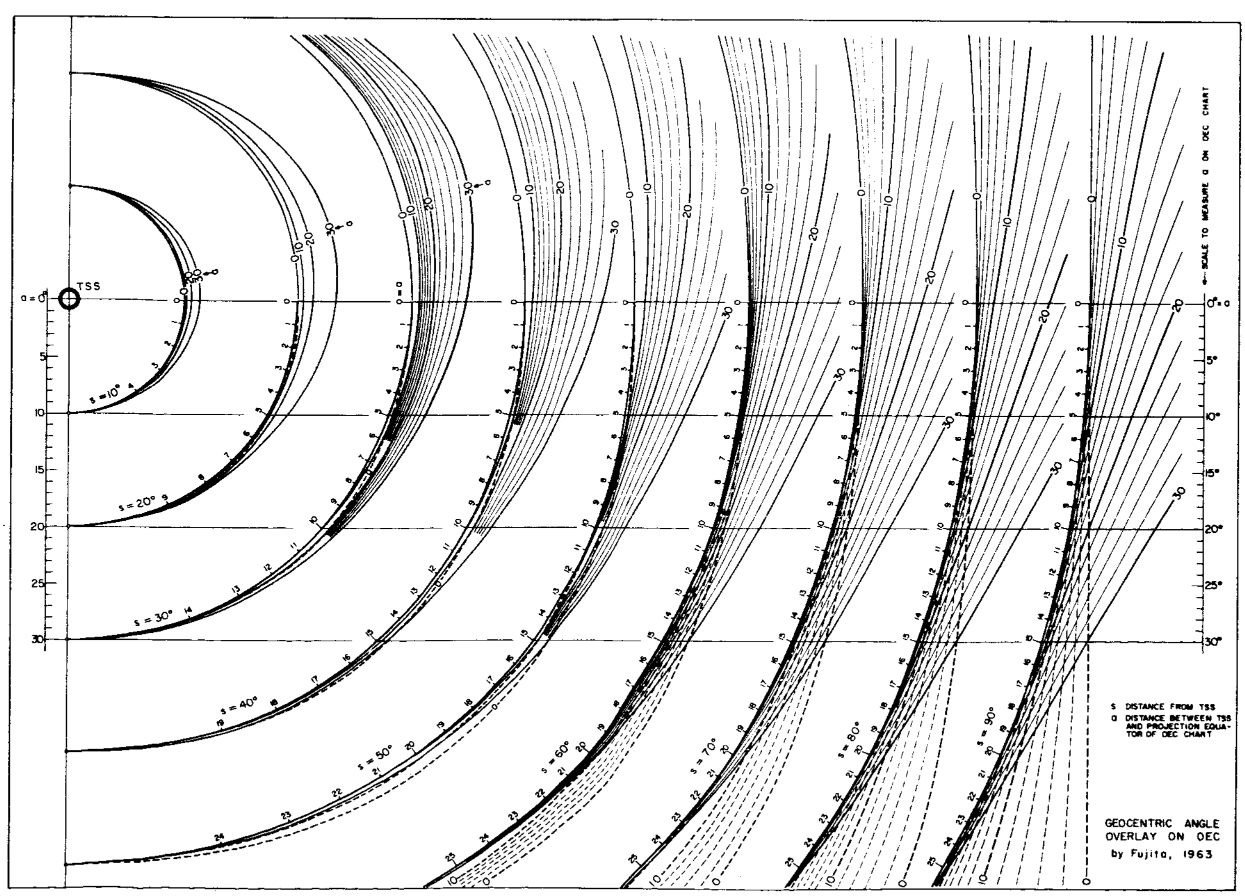




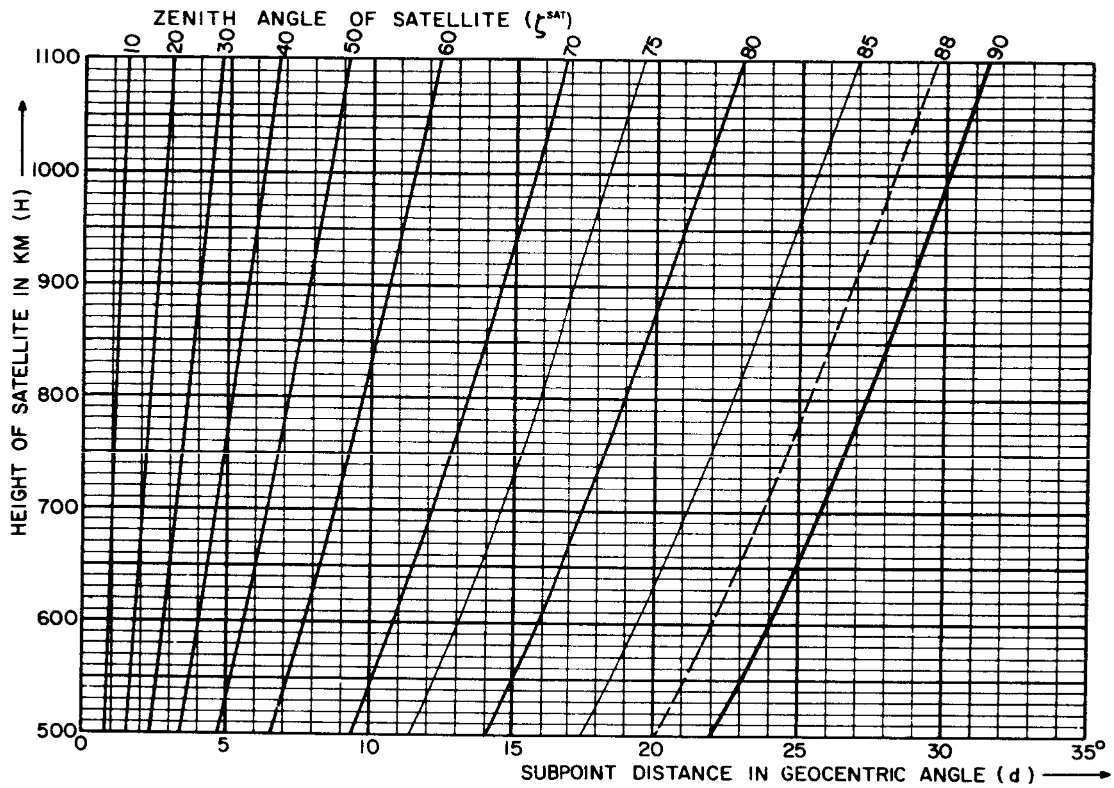
BASIC GEOMETRY

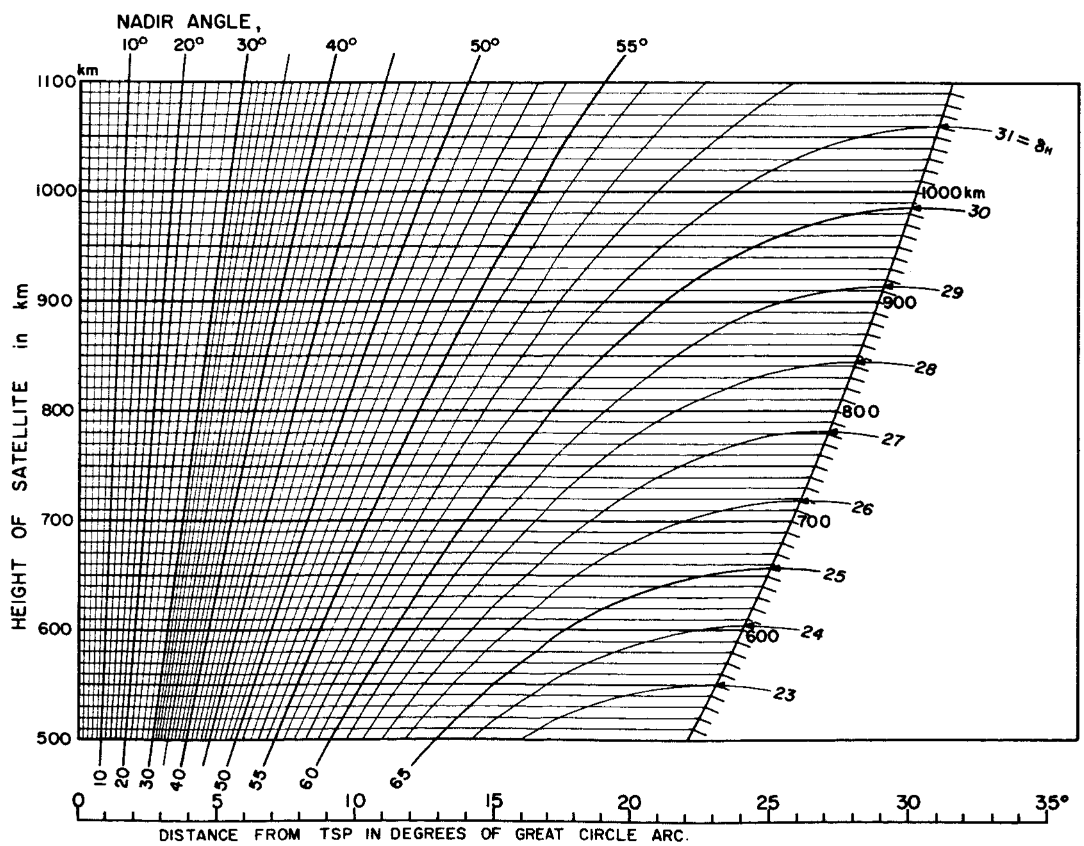
Ih AZIMUTH AND GEOCENTRIC OVERLAYS





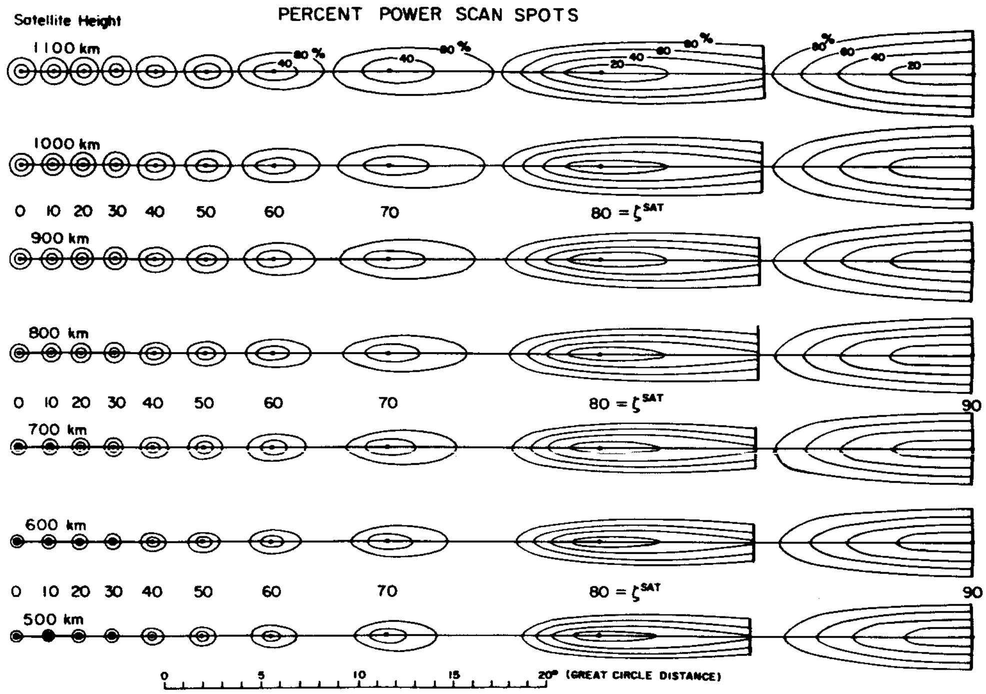
Ii ZENITH-ANGLE AND NADIR-ANGLE CHARTS IN REDUCED SIZE

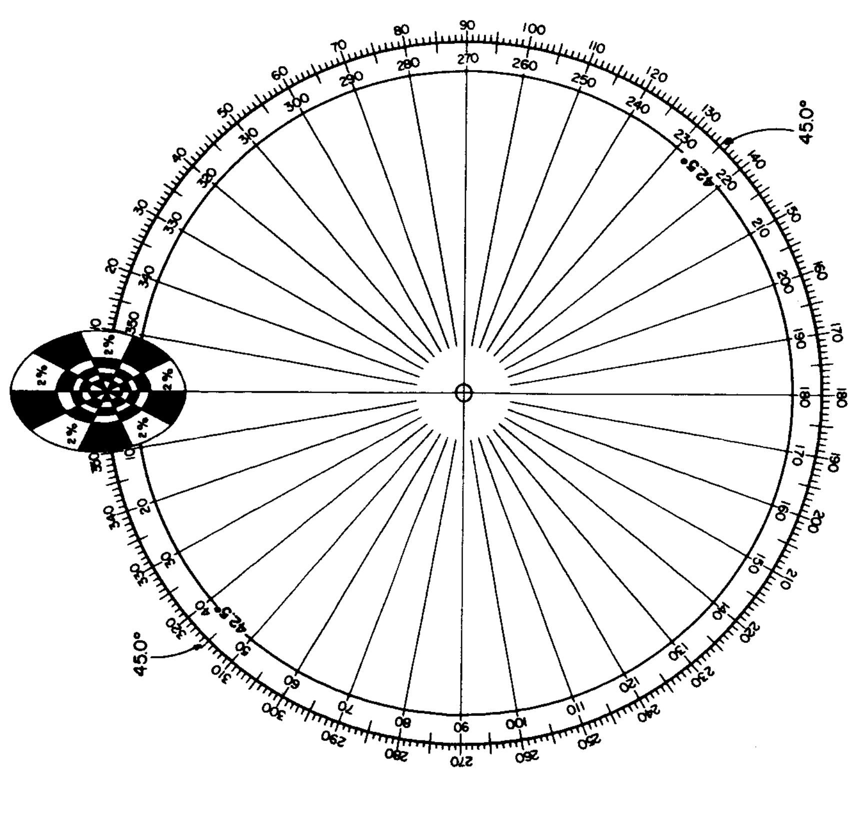




BASIC GEOMETRY

Ij RADIOMETER GRID AND SCAN-SPOT CHART IN REDUCED SIZE





RADIOMETER GRID FOR β = 45.0° & 42.5°
APERTURE 4.4°

II ANALYSIS ON OEC CHART

IIa PRELIMINARY ANALYSIS

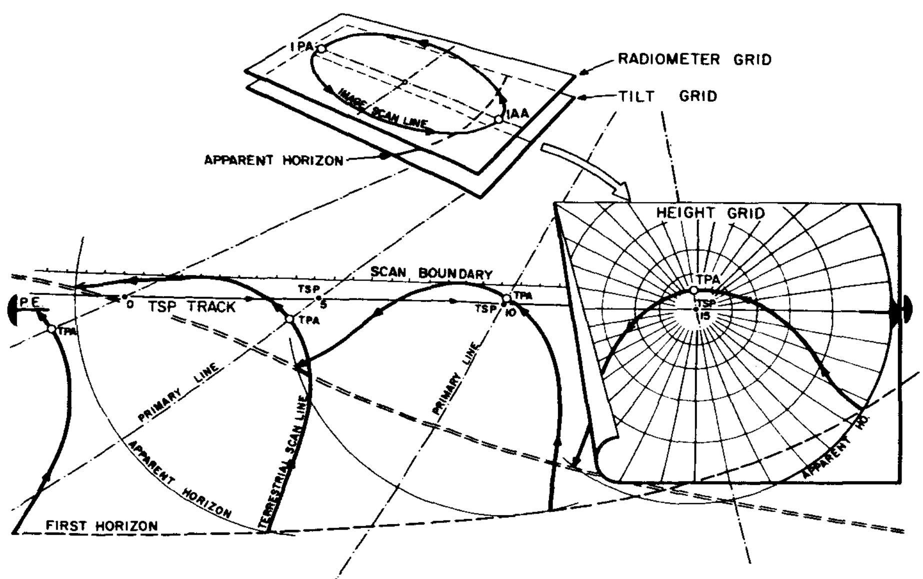
After the determination of the area and the period of research, subpoint and height data are obtained to determine the positions of a satellite over the area of research. Tabulated below is an example of such data as appear in "Definitive AT Map" produced by NASA.

Next we need to know the terrestrial spin-axis point (TSA), the latitude of which may be considered constant during the period of one orbit. Figures 57-61 (MSL Report 14) may be used to obtain the geodetic latitude (ϕ_d^{TSA}) and the right ascension (Ω^{TSA}) of TSA for any orbit of TIROS I-V. The right ascension of Greenwich in Table XIII (MSL Report 14) gives the values at any moment during the years 1960-1970, thus, permitting the computation of the longitude of TSA (θ^{TSA}) as a function of time. Five minute intervals during the period of analysis is sufficient.

Both TSAs and TSPs are plotted on an OEC chart in order to complete the primary lines at five minute intervals. Thus the scan lines at the same intervals are drawn on the chart using the geometry in Ic.

SUBPOINT DATA: ORBIT 132, TIROS III

Time	Latitude	Longitude	Height	Time	Latitude	Longitude	Height	Time	Latitude	Longitude	Height	Time	Latitude	Longitude	Height
1530	47.5	225.9	748	1540	32.4	267.0	760	1550	7.4	292.5	781	1600	-18.9	314.6	807
31	46.8	230.8	749	41	30.1	270.1	762	51	4.8	294.7	783	1	-21.4	317.1	809
32	45.9	235.7	750	42	27.8	273.0	764	52	2.1	296.8	786	2	-23.8	319.6	812
33	44.8	240.3	751	43	25.4	275.7	766	53	-0.6	299.0	788	3	-26.3	322.3	814
34	43.5	244.8	752	44	23.0	278.4	768	54	-3.2	301.1	791	4	-28.6	325.0	816
1535	42.0	249.0	753	1545	20.5	280.9	770	1555	-5.9	303.3	794	1605	-30.9	327.9	818
36	40.4	253.0	755	46	17.9	283.4	772	56	-8.5	305.5	796	6	-33.0	331.0	820
37	38.5	256.8	756	47	15.3	285.7	774	57	-11.2	307.7	799	7	-35.1	334.2	822
38	36.6	260.4	757	48	12.7	288.0	776	58	-13.8	309.9	801	8	-37.1	337.6	824
39	34.6	263.8	759	49	10.1	290.3	778	59	-16.3	312.2	804	9	-39.0	341.1	825



ANALYSIS ON OEC CHART

IIb PERINADIR TRACK

The nadir angle of a perinadir (TPA) as defined in Ia is computed from

$$\eta^{TPA} = \eta_s - \beta .$$

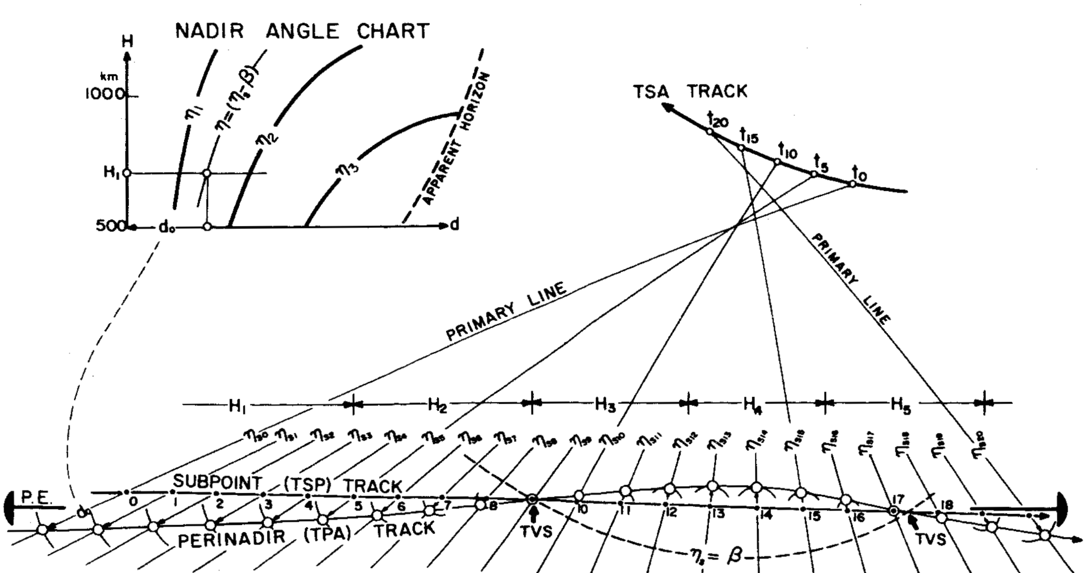
Namely, the nadir angle of a perinadir is the satellite nadir-angle less the inclination of the axis of a scanning radiometer. Since the satellite nadir-angles are computed on an OEC chart by using the OEC overlay, the nadir angles of perinadirs can be computed as a function of time.

An example of such values for orbit 132 R/O 133, TIROS III, is tabulated. The negative values of the nadir angle of TPA indicate that the perinadirs are located between TSP and TSA.

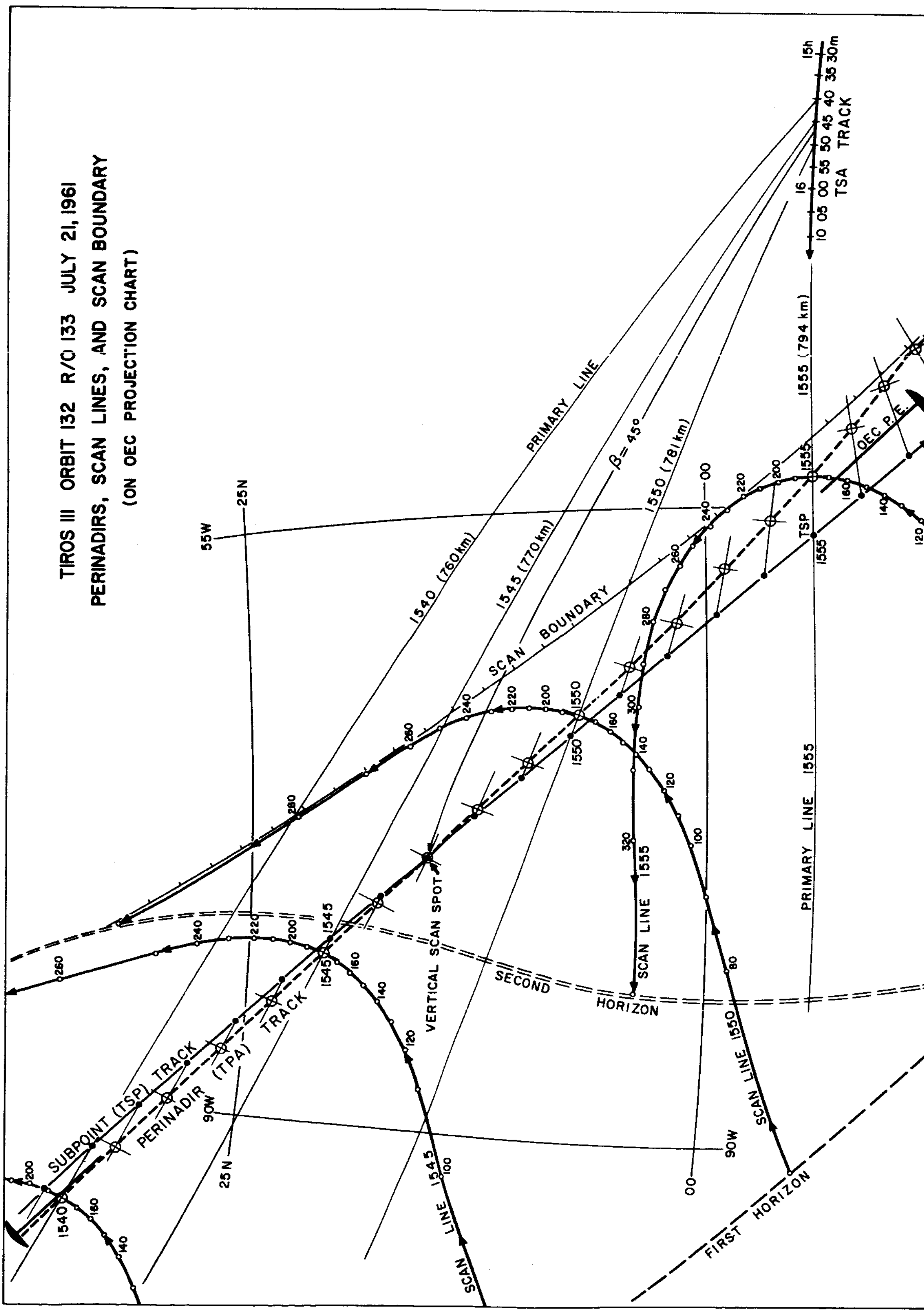
Time	1540	1541	1542	1543	1544	1545	1546	1547	1548	1549
η_s	69.2	65.8	62.2	58.5	55.1	51.7	48.2	45.0	41.2	38.1
η^{TPA}	24.2	20.8	17.2	13.5	10.1	6.7	3.2	0.0	-3.8	-6.9
H	760	762	764	766	768	770	772	774	776	778

Time	1550	1551	1552	1553	1554	1555	1556	1557	1558	1559
η_s	34.9	31.7	28.6	25.3	22.8	20.1	18.0	16.3	15.1	14.9
η^{TPA}	-10.1	-13.3	-16.4	-19.7	-22.2	-24.9	-27.0	-28.7	-29.9	-30.1
H	781	783	786	788	791	794	796	799	801	804

The nadir-angle chart (Page 10) gives the subpoint distance as a function of the satellite height and the nadir angle of a perinadir, thus permitting us to determine the perinadirs at one minute intervals. The perinadir and the subpoint tracks cross each other at the points with the great circle distance β from the TSA. These points are called the vertical scan points (TVS) which are scanned vertically from a satellite.



ANALYSIS ON OEC CHART



ANALYSIS ON OEC CHART

IIc SCAN SPOTS AND ZENITH ANGLE OF SATELLITE

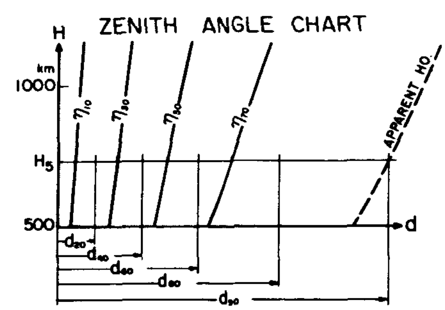
As a result of the change in satellite nadir-angle, some areas on the earth have a possibility of being scanned again a few minutes later. For the analysis of radiation data, the earlier and the later scans should be distinguished and analysed separately.

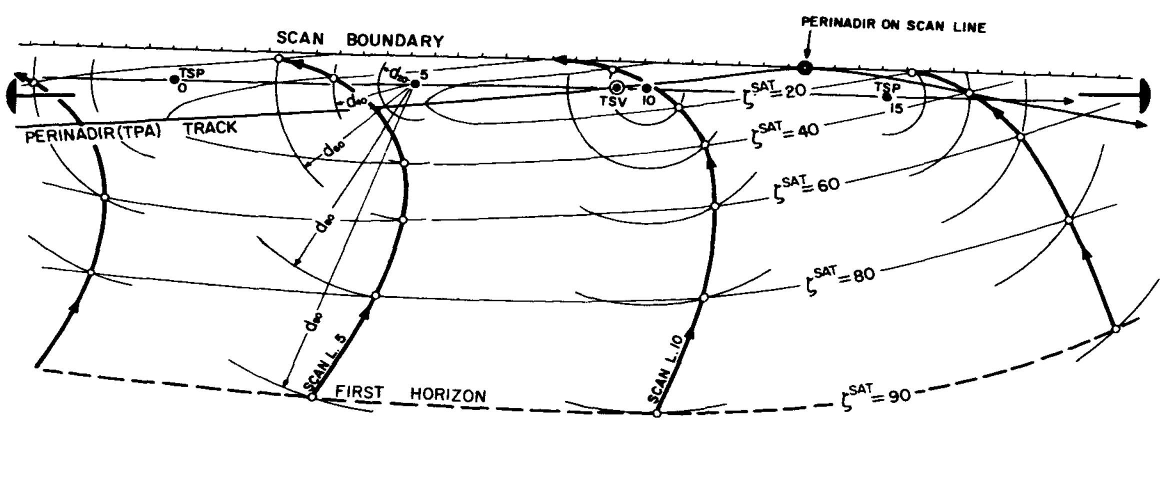
The group of scan lines occurring early are called initial scan lines, and those occurring later, the secondary scan lines. The figure below gives only the initial scan lines which originate on the first horizon and terminate on the scan boundary.

The zenith angle of the satellite viewed from a scan spot is the function of both satellite height and the subpoint distance. The zenith-angle chart (Page 10) thus gives us immediately the subpoint distance of the scan point for a given zenith angle of satellite. We may assume that a line of equal subpoint distance is a circle around a TSP as long as it is located within a few degrees from the OEC projection equator.

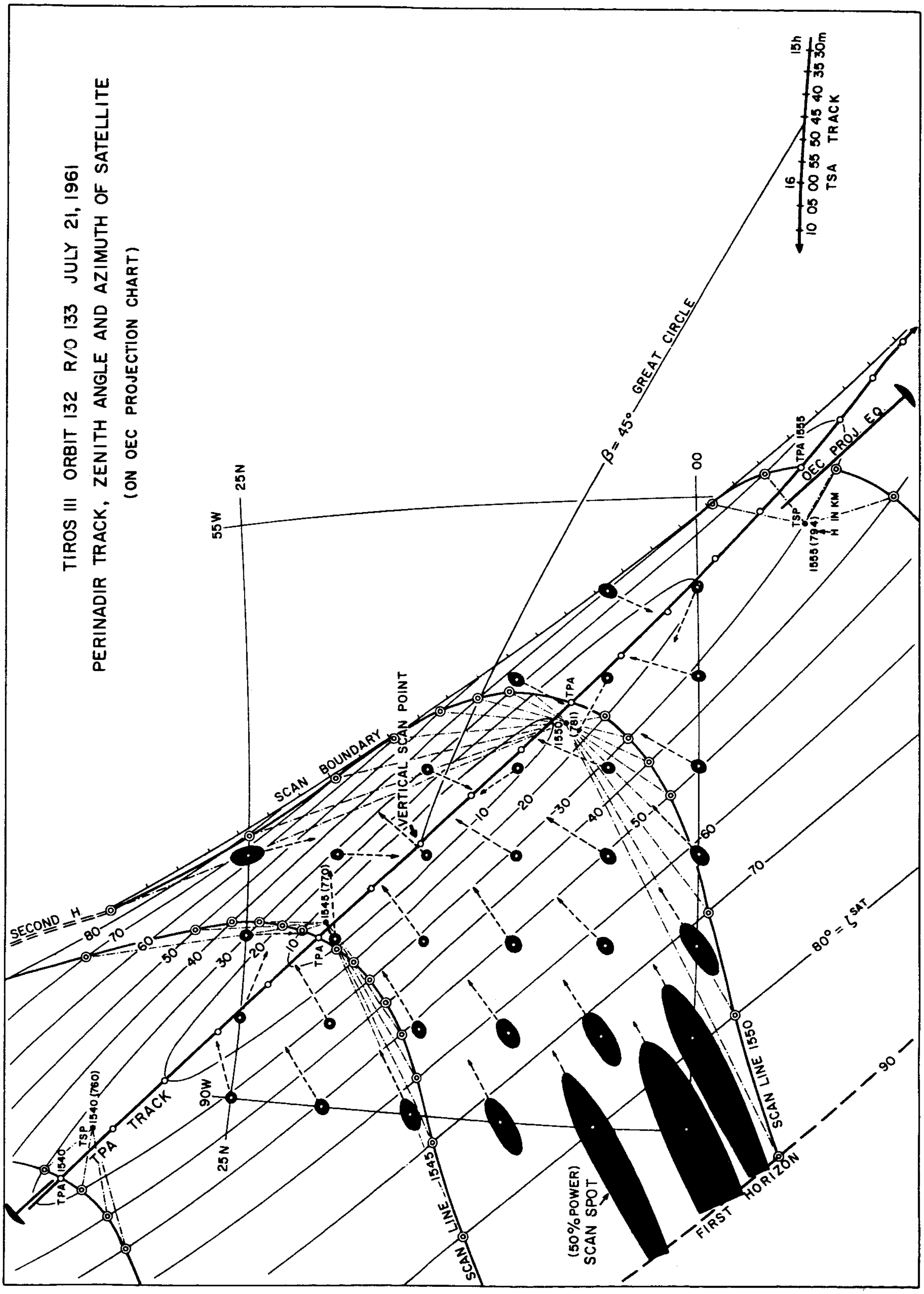
An OEC Overlay or a height grid is used to determine the azimuth of satellite viewed from a scan point. An example appears on the next page.

Thus knowing the azimuth and the zenith angle of satellite at a number of scan points, the scan-spot chart (Page 11) is placed under the OEC chart to make copies of proper scan spots. The black areas on the next page designate the 50%-power scan spots.





ANALYSIS ON OEC CHART



ANALYSIS ON OEC CHART

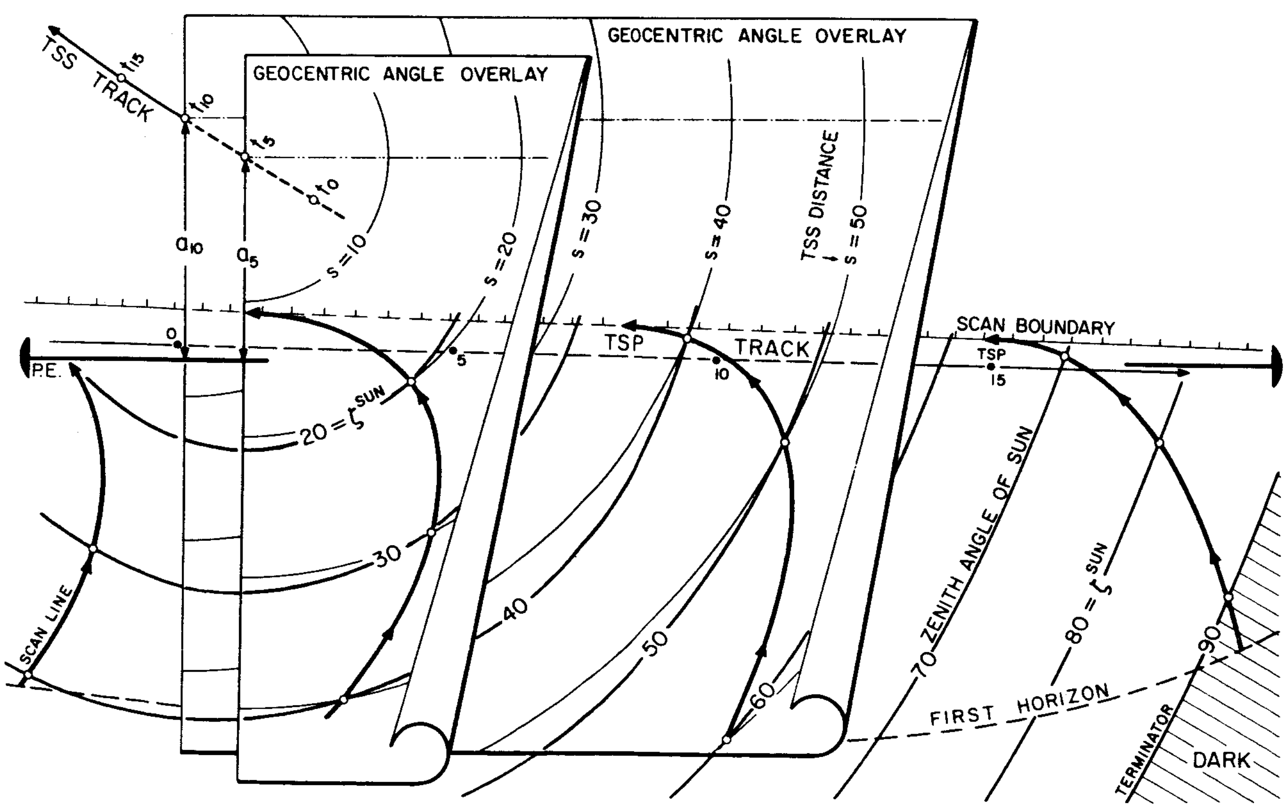
Id ZENITH ANGLE AND AZIMUTH OF THE SUN

The zenith angle of the sun viewed from a scan spot is obtained by using the geocentric angle overlay (Pages 6 and 9) with its origin at the TSS on the OEC chart. The overlay will give us the isolines of the zenith angle of the sun at 10 degree intervals. It is, therefore, done graphically to select on a scan line the points with ζ^{SUN} = 10, 20, 30, ---- 90.

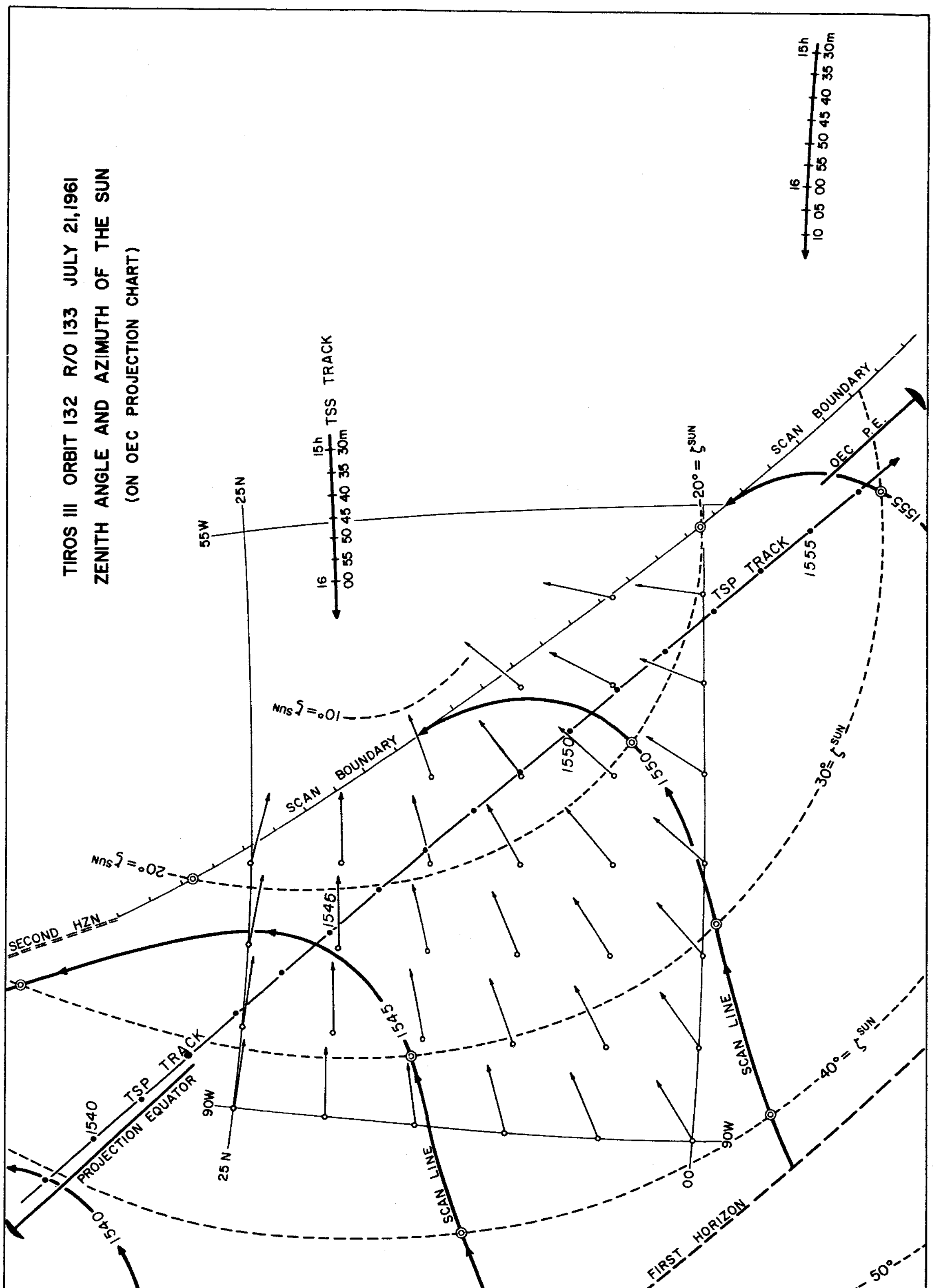
Five-minute scan lines drawn on OEC charts are sufficient to determine the isolines of ζ^{SUN} at 10 degree intervals. These isolines can later be transferred to any other projection.

The line of ζ^{SUN} = 90 is the terminator on the earth and no reflected light is expected beyond this line. It is sometimes of importance to draw the terminator on the OEC to learn the area of the sun-lit hemisphere.

An example on the next page shows the isolines of ζ^{SUN} and the azimuth of the sun viewed from each scan point. The azimuths are drawn by connecting TSS and each scan point with a great circle on the OEC overlay.



ANALYSIS ON OEC CHART



ANALYSIS ON OEC CHART

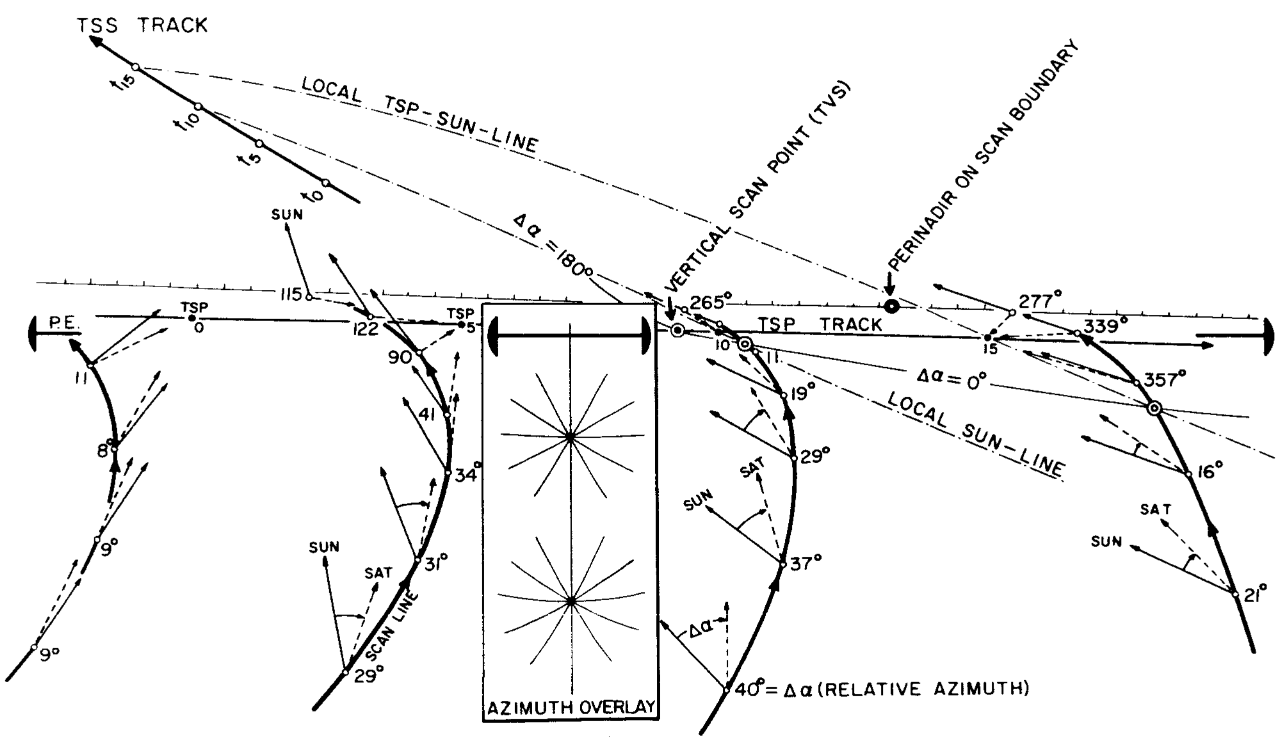
IIe RELATIVE AZIMUTH OF SATELLITE

The relative azimuth of satellite viewed from a scan point is the direction of a satellite measured clockwise from the azimuth of the sun.

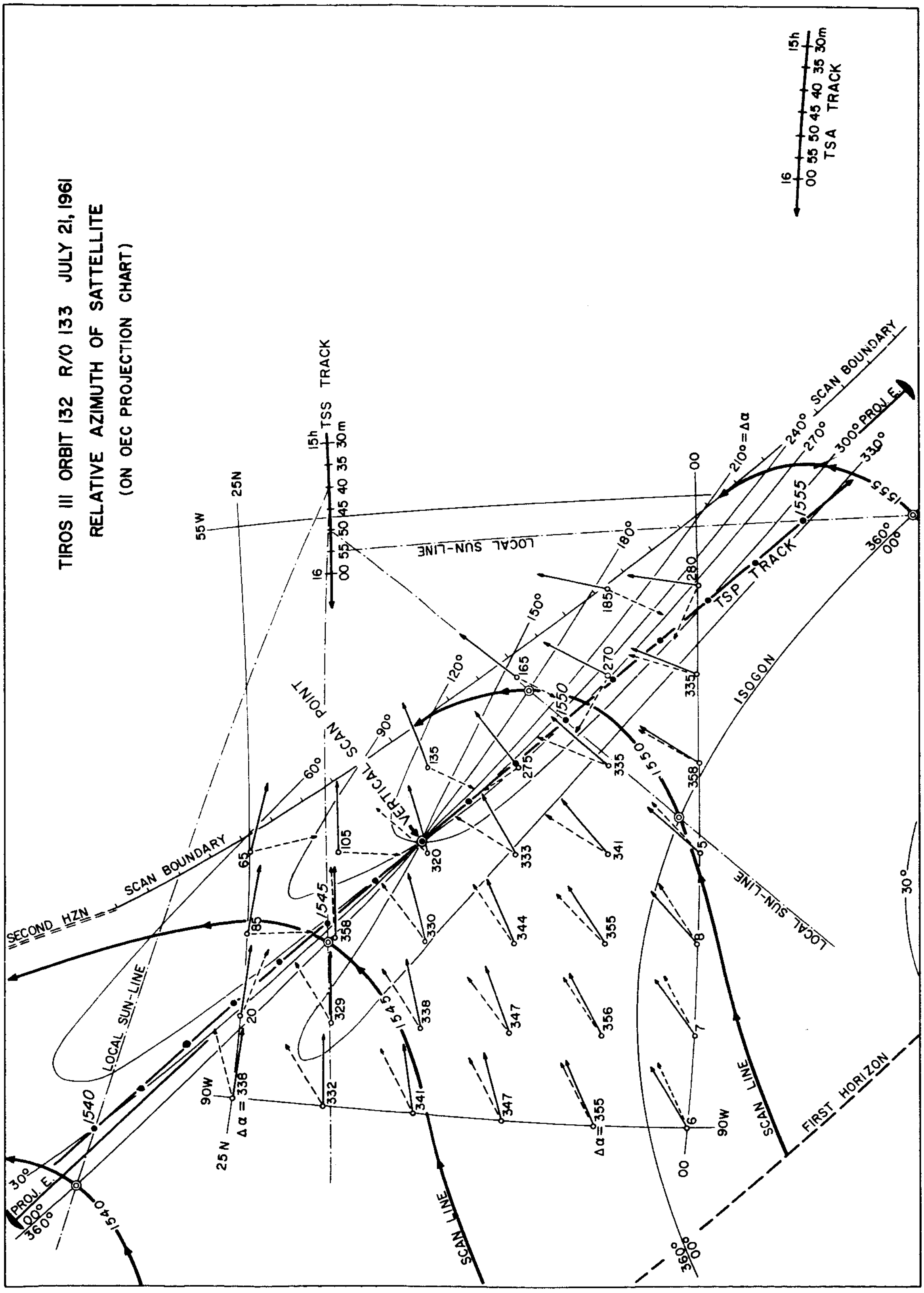
The azimuths of both the sun and the satellite are drawn on an OEC chart by connecting a scan point with TSS and TSP, respectively. The relative azimuth, the angle between them, is measured by placing the azimuth overlay onto the OEC.

As shown in the figure below, the local TSP-sun-line intersects the scan line at the points for which the relative azimuth is either 0 or 180 degrees. There are cases where zero, one, or two intersections exist on one scan line. The cases depend upon the positions of TSS and TSA relative to the TSP track.

A figure on the next page gives a specific example. The isogons of the relative azimuth are fairly complicated; however, the vertical scan point (TVS) is always the point from which the isogons 0 through 360 degrees depart.



ANALYSIS ON OEC CHART



III SPECIFIC EXAMPLES

IIIa RADIATION DATA

In order to perform research using TIROS radiation data, researchers will probably start from one of the following materials:

1 GRID PRINT RADIATION MAP
2 FMRT LISTING
3 FMR TAPE.

The examples presented here deal with the second material, the FMRT Listing. The FMRT Listing of TIROS III radiation data includes, as shown below, the azimuths and the nadir angles of the scan points viewed from the satellite at the moment of the scan, the latitude and the longitude of each scan point, and the equivalent black body temperature or reflected solar energy measured by each of the five scanning radiometers.

SCAN LINE NUMBER 4

AZIMUTH	NADIR ANGLE	LONGITUDE	LATITUDE	6.0-6.5 MU	8.0-12 MU	0.2-5.0 MU	7.5-30 MU	.55-.75 MU
235.98	56.94	86.67	9.34	228.37	247.50	119.12	247.75	18.62
223.30	54.18	84.54	10.32	237.75	263.25	106.37	249.12	11.12
217.06	50.14	82.73	11.19	233.25	268.87	59.25	255.25	3.75
215.69	45.11	81.20	11.97	233.25	268.12	31.50	254.00	0.
217.64	39.41	79.93	12.68	239.50	272.25	24.50	258.62	0.
221.34	33.33	78.89	13.33	237.25	276.75	10.62	263.00	0.
225.25	27.17	78.05	13.92	238.87	281.12	17.62	267.37	0.
227.80	21.24	77.39	14.48	237.75	271.37	31.50	265.25	0.
227.42	15.83	76.88	15.01	242.37	274.00	17.62	261.87	0.
222.57	11.26	76.49	15.53	238.87	278.87	10.62	267.37	0.
211.67	7.81	76.19	16.05	238.37	274.87	0.	265.25	0.
163.36	7.69	75.84	16.59	235.50	275.75	3.75	264.12	0.
113.34	8.83	75.57	17.15	233.25	274.87	10.62	264.12	0.
67.52	11.06	75.35	17.75	236.12	274.87	10.62	260.75	0.
31.78	14.21	75.21	18.39	237.75	278.87	17.62	269.62	0.
12.03	18.12	75.12	19.08	238.87	281.12	3.75	265.25	0.
14.16	22.62	75.11	19.83	238.37	276.75	31.50	265.25	0.
44.05	27.53	75.16	20.67	227.75	274.87	31.50	264.12	0.
107.62	32.69	75.27	21.58	237.25	279.87	10.62	264.12	1.87
210.75	37.92	75.46	22.59	226.50	276.75	10.62	264.12	1.87
359.34	43.06	75.70	23.70	240.12	274.87	17.62	265.25	0.
559.29	47.94	76.02	24.93	234.87	272.25	10.62	263.00	0.
816.49	52.38	76.39	26.29	233.25	268.12	10.62	257.50	0.
1136.83	56.22	76.84	27.78	233.25	262.50	31.50	249.12	0.

SCAN LINE NUMBER 8

AZIMUTH	NADIR ANGLE	LONGITUDE	LATITUDE	6.0-6.5 MU	8.0-12 MU	0.2-5.0 MU	7.5-30 MU	.55-.75 MU
238.39	60.42	89.08	6.59	220.12	230.00	100.00	238.25	14.87
226.93	57.38	86.10	7.88	228.37	261.62	87.12	254.00	13.00
220.92	53.38	83.60	9.01	234.87	270.50	66.25	255.25	0.
219.01	48.63	81.54	9.99	233.75	266.50	73.25	252.75	11.12
219.84	43.35	79.86	10.84	229.62	235.75	138.25	227.00	7.37
222.03	37.77	78.52	11.58	232.62	245.00	73.25	245.00	1.87
224.24	32.09	77.47	12.23	237.75	273.12	10.62	263.00	0.
225.09	26.54	76.68	12.81	241.75	274.87	10.62	259.62	0.
223.23	21.33	76.10	13.34	243.00	276.75	17.62	261.87	0.
217.29	16.69	75.68	13.84	235.50	273.12	59.25	258.62	9.25
205.91	12.83	75.37	14.33	234.37	271.37	80.12	256.37	0.
171.40	10.83	74.98	14.86	232.00	271.37	17.62	260.75	3.75
132.81	9.84	74.65	15.41	240.12	264.12	10.62	251.62	1.87
92.85	9.84	74.39	15.98	230.25	264.12	59.25	255.25	0.
54.26	10.83	74.20	16.58	236.62	277.87	59.25	260.75	0.
19.75	12.83	74.06	17.22	238.37	273.12	17.62	263.00	0.
-3.15	16.69	73.88	17.77	234.37	274.87	38.50	256.37	1.87
-17.74	21.33	73.78	18.41	230.25	274.00	31.50	266.37	0.
-22.49	26.53	73.79	19.18	225.37	279.87	3.75	265.25	0.
-15.88	32.07	73.92	20.13	232.00	282.25	17.62	264.12	0.
3.59	37.73	74.22	21.30	237.75	274.87	10.62	260.75	0.
37.46	43.31	74.69	22.72	232.62	270.50	10.62	256.37	0.
87.23	48.57	75.37	24.45	234.87	272.25	17.62	259.62	0.
154.43	53.30	76.28	26.52	241.25	276.75	17.62	264.12	0.
240.57	57.29	77.44	28.98	230.87	265.62	17.62	257.50	3.75
347.17	60.31	78.87	31.87	227.75	247.50	52.37	237.00	9.25

SPECIFIC EXAMPLES

The Grid Print Radiation Map and the FMR Tape also gives similar values when they are placed or plotted on a proper geographic location.

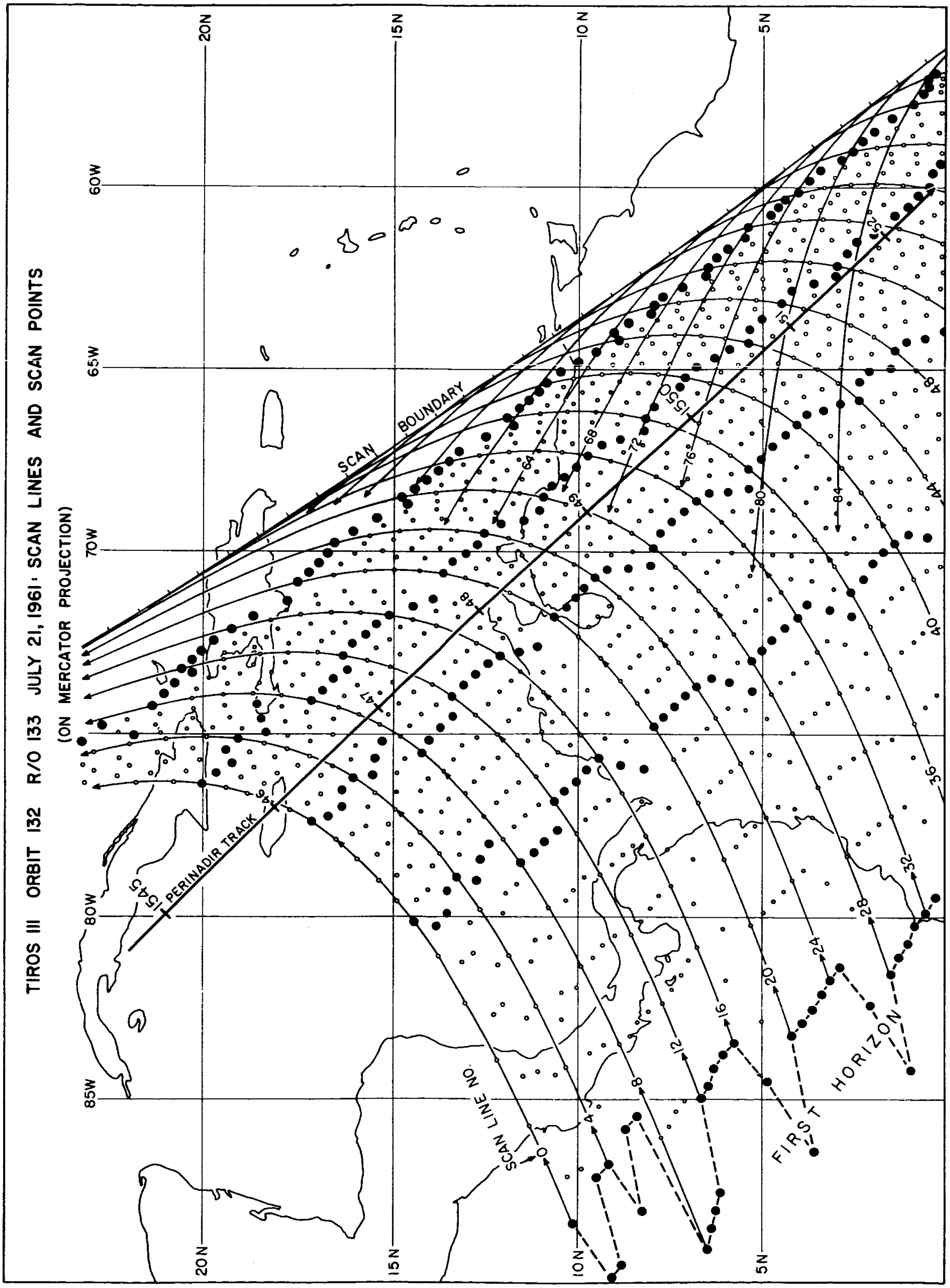
The first chart in the example presents the locations of the scan points given by FMR Listing for 10 minute intervals beginning at 1545 GMT, July 21, 1961. The data were recorded on orbit 132 with readout on the next orbit. Each fifth point as well as the first horizon is painted black since it is the only computed point while the others are interpolated ones. Every fourth scan line is entered on the chart in order that the exact time can be determined from the perinadir track transcribed from the OEC chart on page 14. Most of the area was scanned by the group of initial scan lines; however, the area east of the 70° W longitude was also scanned by the secondary scan lines characterized by much larger zenith angle of satellite.

The radiation maps of channels 1, 2 and 4 presented on pages 24, 25 and 27 include the equivalent black body temperature above 200 degrees centigrade. These maps also show the isolines of the zenith angle of satellite. The vertical scan point coincides with the perinadir at 1547 located near the northwest fringe of Hurricane Anna. It is seen that the hurricane was in such a position relative to the satellite that she was scanned with extremely small nadir angles.

Channels 3 and 5 measure the reflected sun light. It is, therefore, important to know the zenith angle of the sun. The maps for these channels appearing on pages 25 and 27 thus include the isolines of ζ^{SUN} at 10 degree intervals. At the top, the conversion scale between ζ^{SUN} and $\overline{W}^* \cos \zeta^{SUN}$ is given, where $\overline{W}^*$ is the particular value of $\overline{W}$ as defined in the Users' Manual, TIROS III, Radiation Data. $\overline{W}^*$ for channel 3 and 5 are, respectively, 763.8 watts/m^2 and 108.6 watts/m^2 . The reflectivity can be computed on the chart by dividing the measured value by $\overline{W}^* \cos \zeta^{SUN}$ on the top scale of the radiation maps.

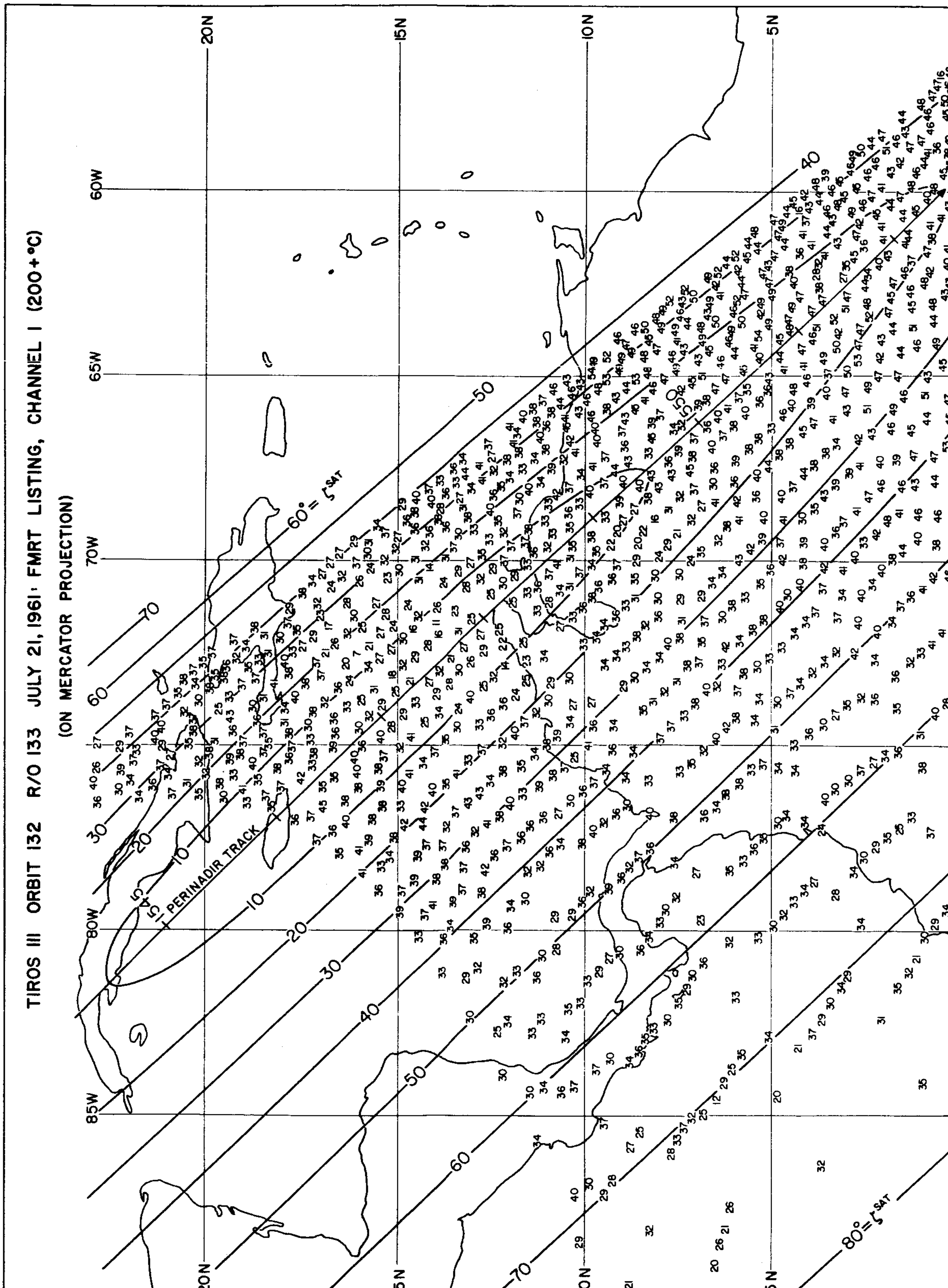
SPECIFIC EXAMPLES

IIIb SCAN POINTS AND SCAN LINES



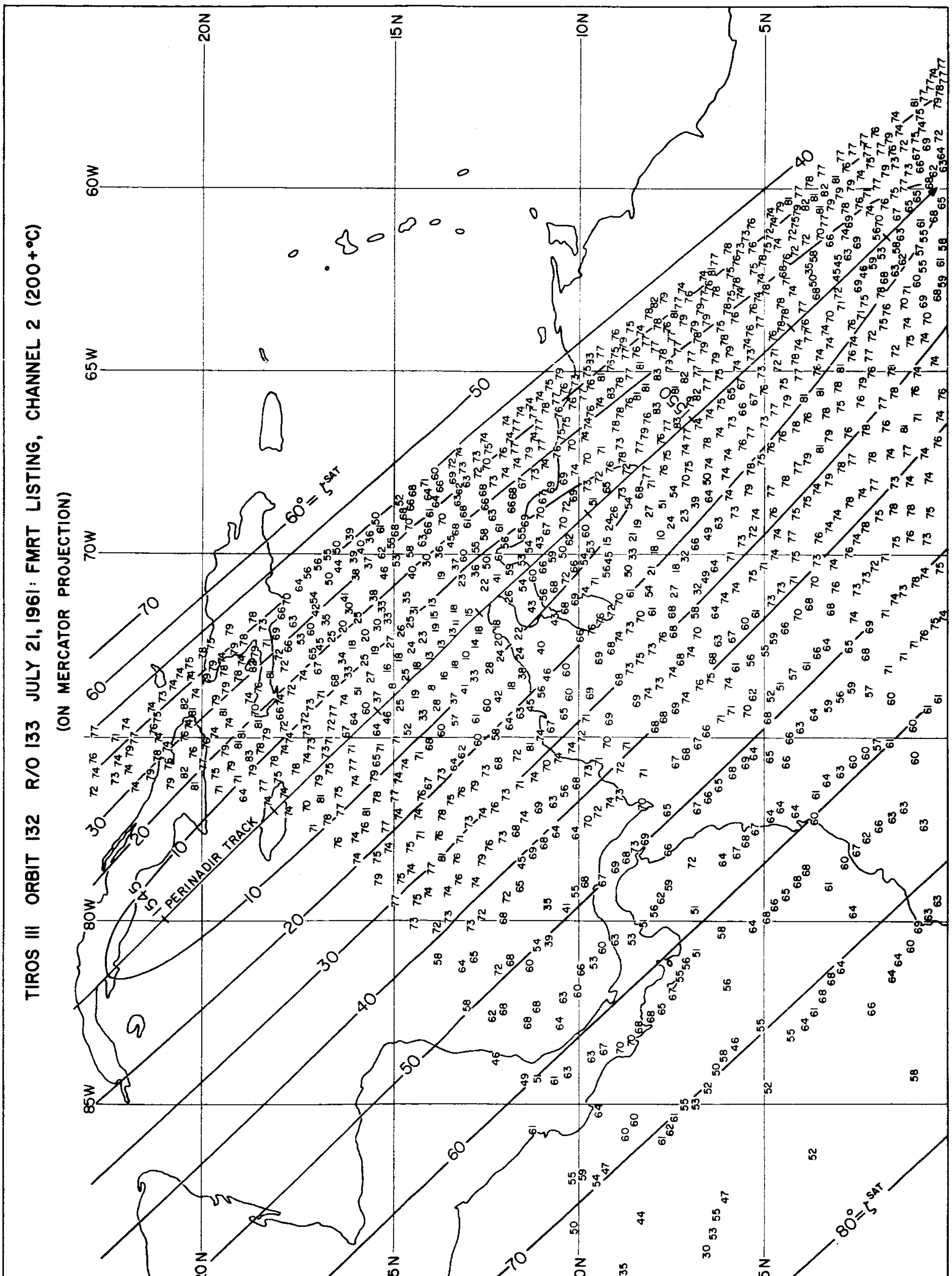
SPECIFIC EXAMPLES

IIIc CHANNEL 1



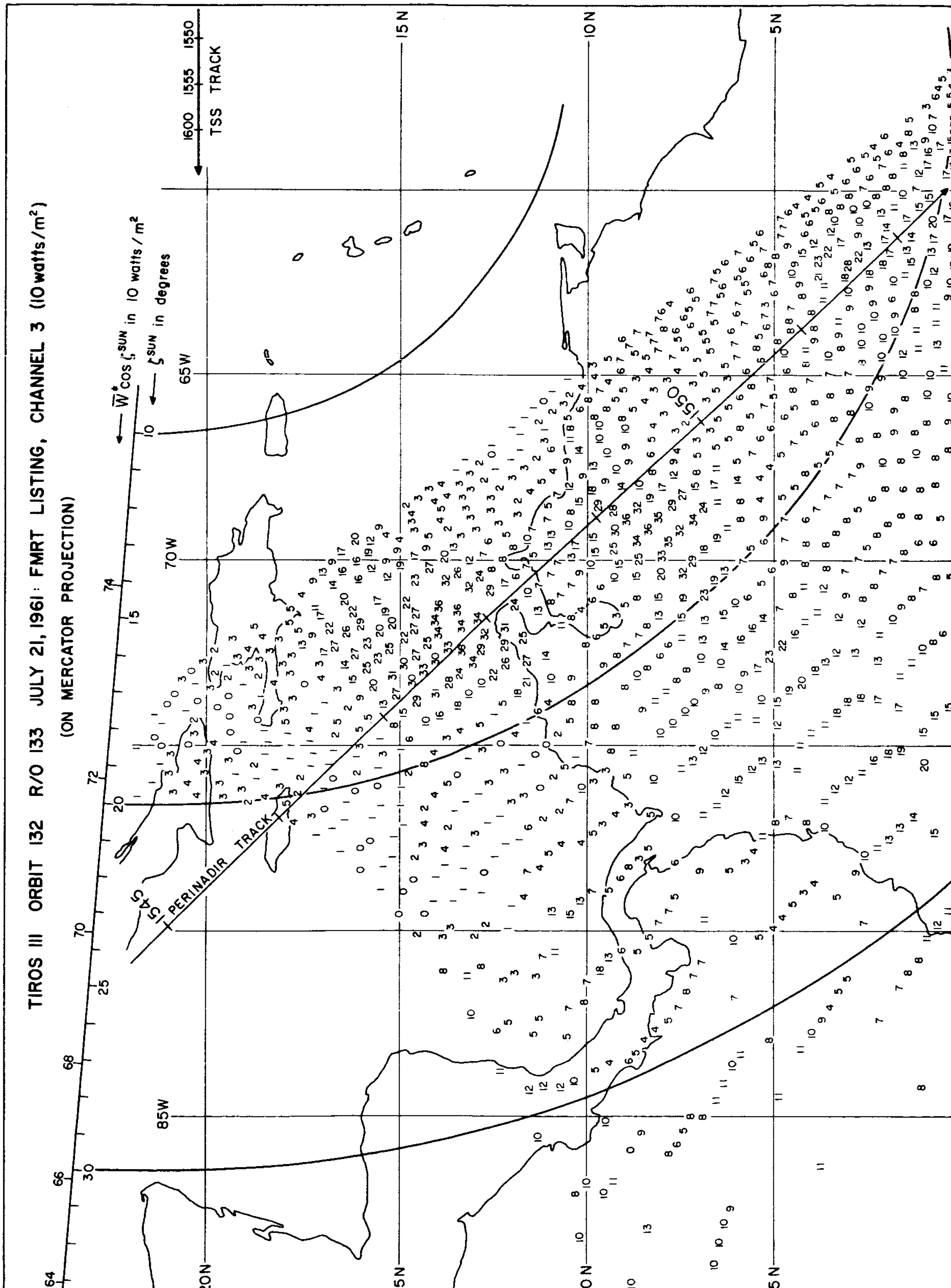
SPECIFIC EXAMPLES

IIId CHANNEL 2



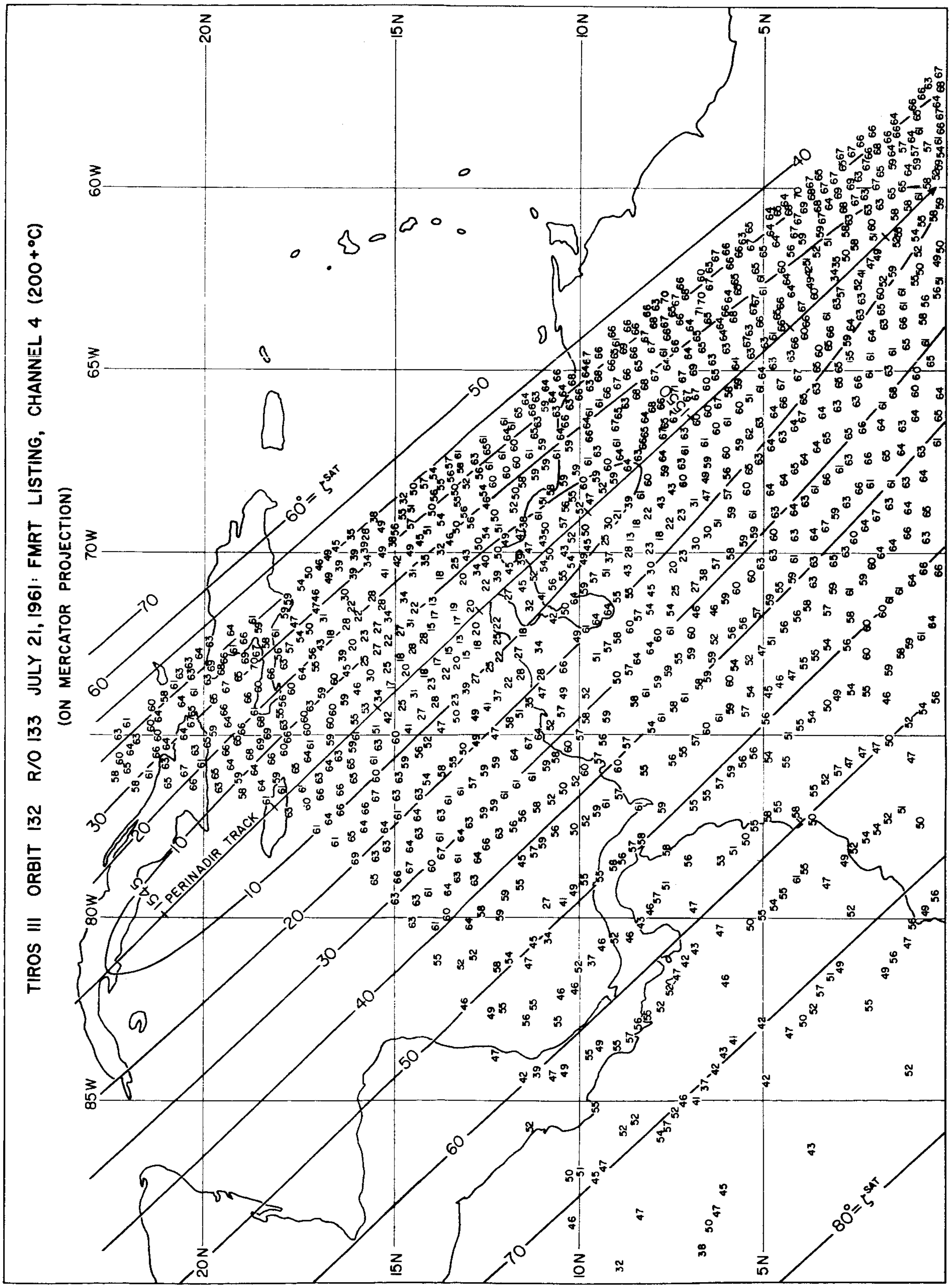
SPECIFIC EXAMPLES

IIIe CHANNEL 3



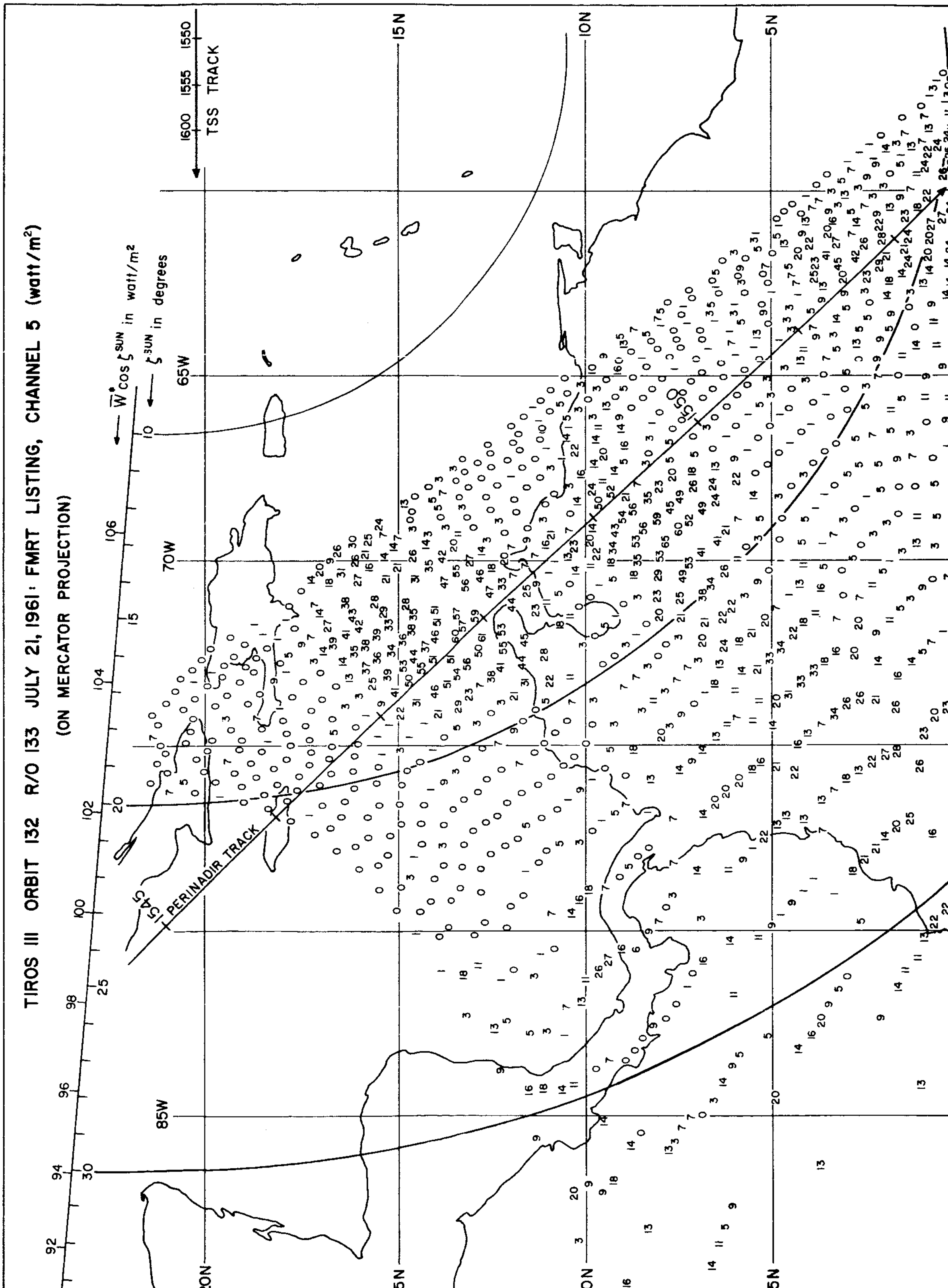
SPECIFIC EXAMPLES

IIIf CHANNEL 4



SPECIFIC EXAMPLES

IIIg CHANNEL 5



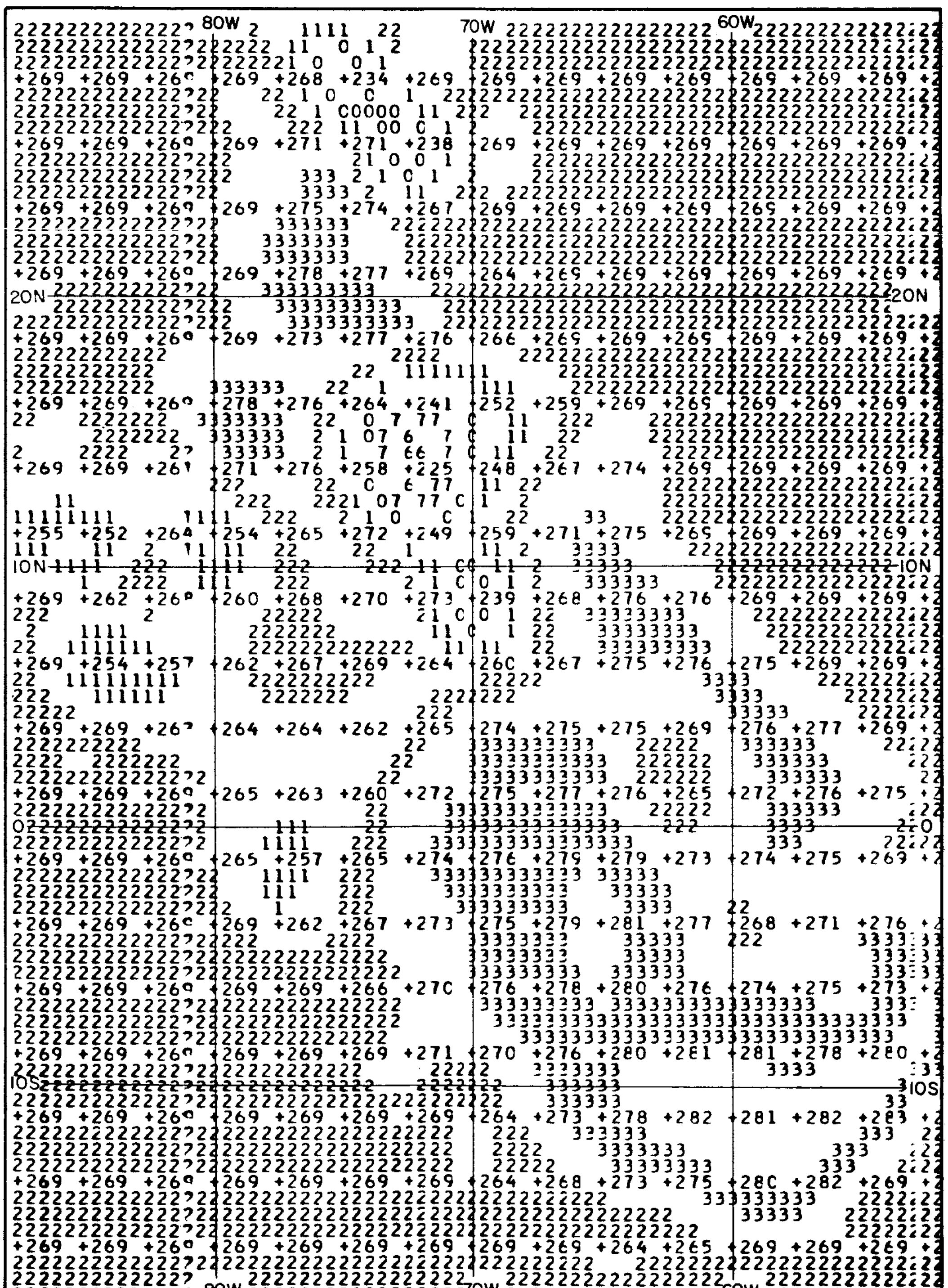
SUBJECT INDEX

Some of the terms used in this text are tentative and subject to change when a more complete survey of the terminology is finished.

APPENDIX

Aa CHANNEL 2 GRID PRINT RADIATION MAP, TIROS III, ORBIT 132

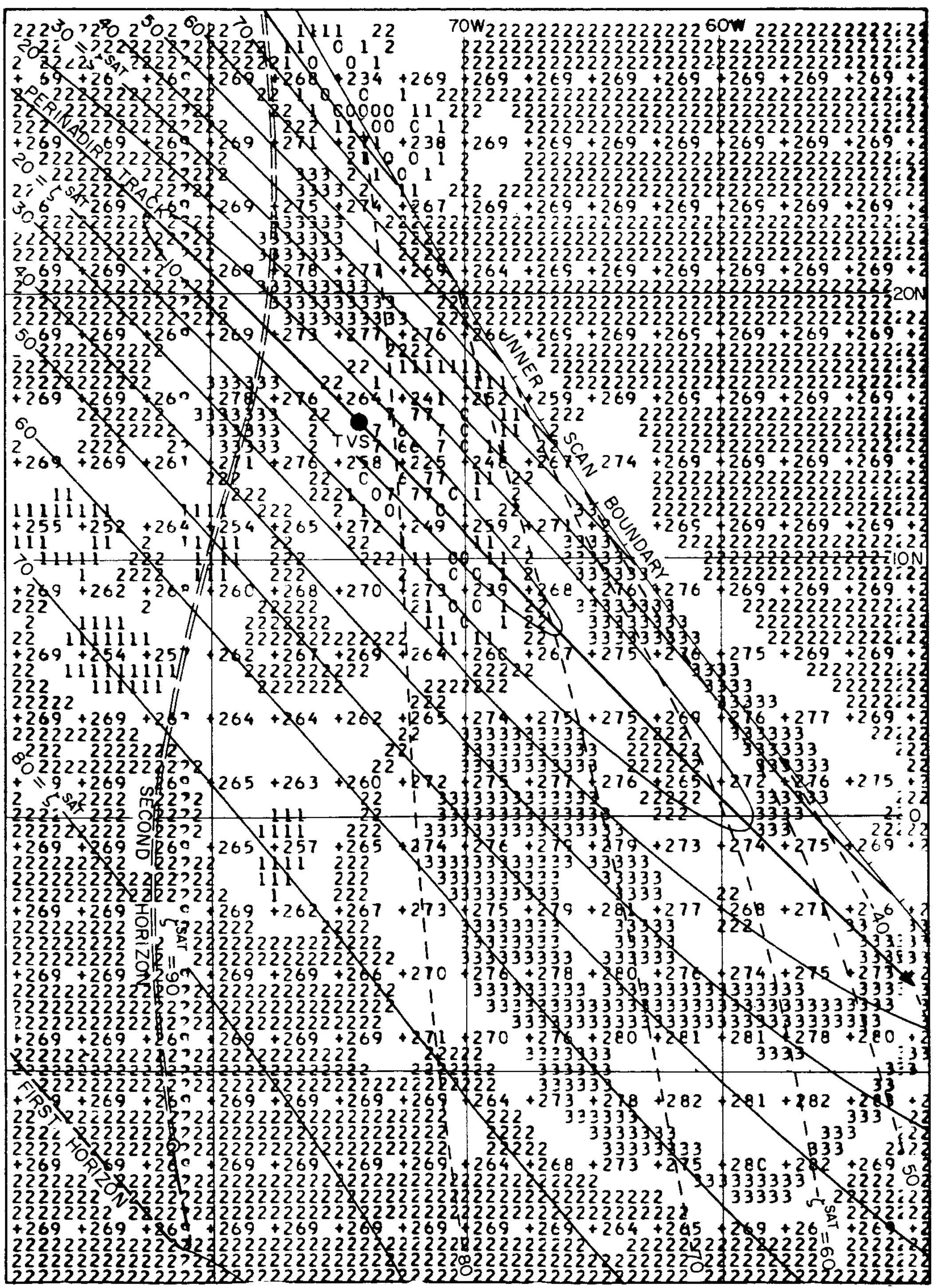
This chart produced by MSL includes the data points within the 58^{o} nadir-angle limit. This limit corresponds to about 72^{o} of the zenith angle of satellite for the area of the grid print map.



APPENDIX

Ab CHANNEL 2 GRID PRINT RADIATION MAP, TIROS III, ORBIT 132

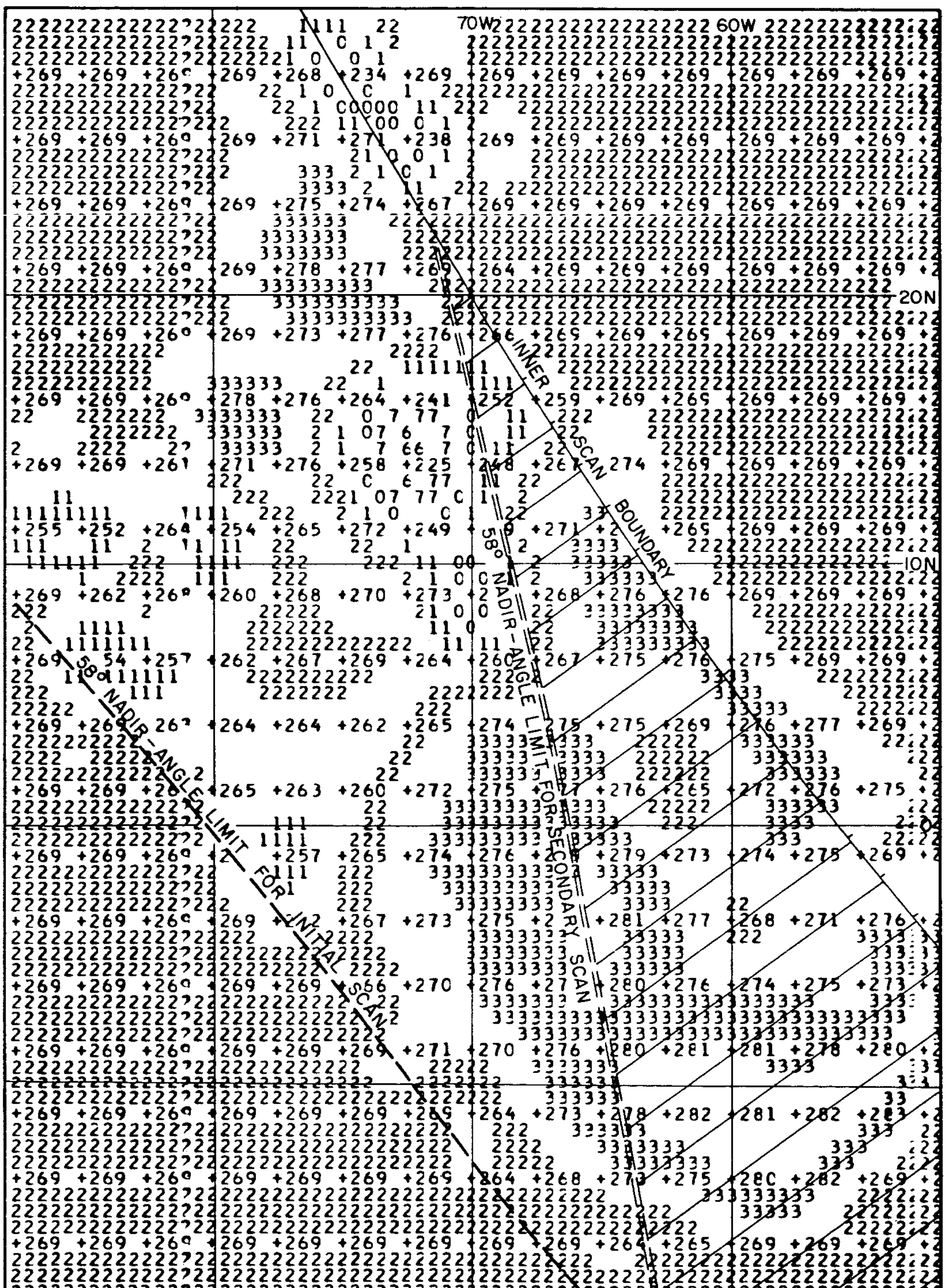
The isolines of the zenith angle of satellite for both initial (solid lines) and secondary scans (broken lines) are superimposed on the grid print map. The point TVS on the perinadir track denotes the vertical scan point.



APPENDIX

Ac CHANNEL 2 GRID PRINT RADIATION MAP, TIROS III, ORBIT 132

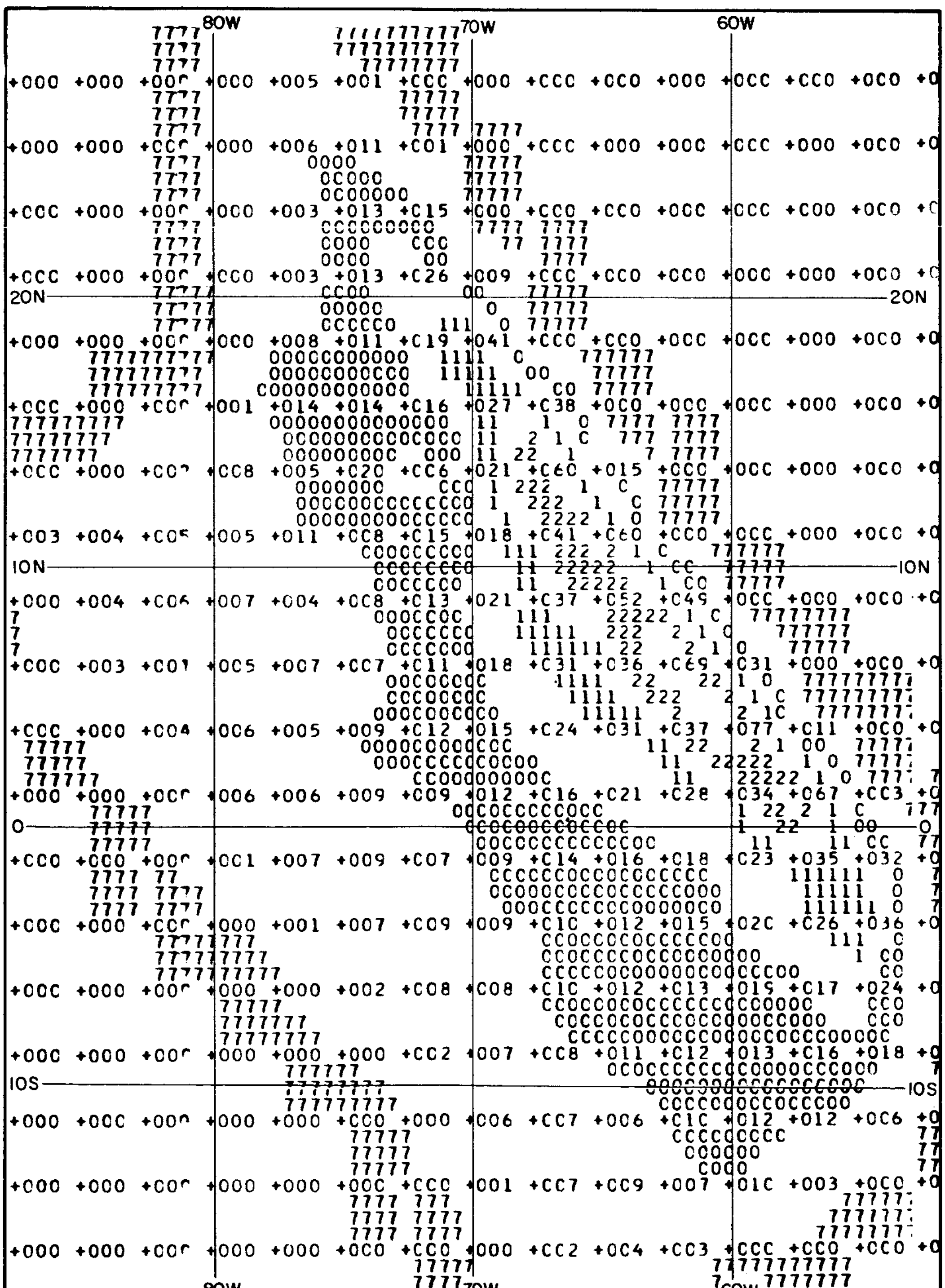
The scan boundary and the 58^{o} nadir-angle limit of the grid print map. The shaded area includes the data from the initial and secondary scans.



APPENDIX

Ad POPULATION MAP, TIROS III, ORBIT 132

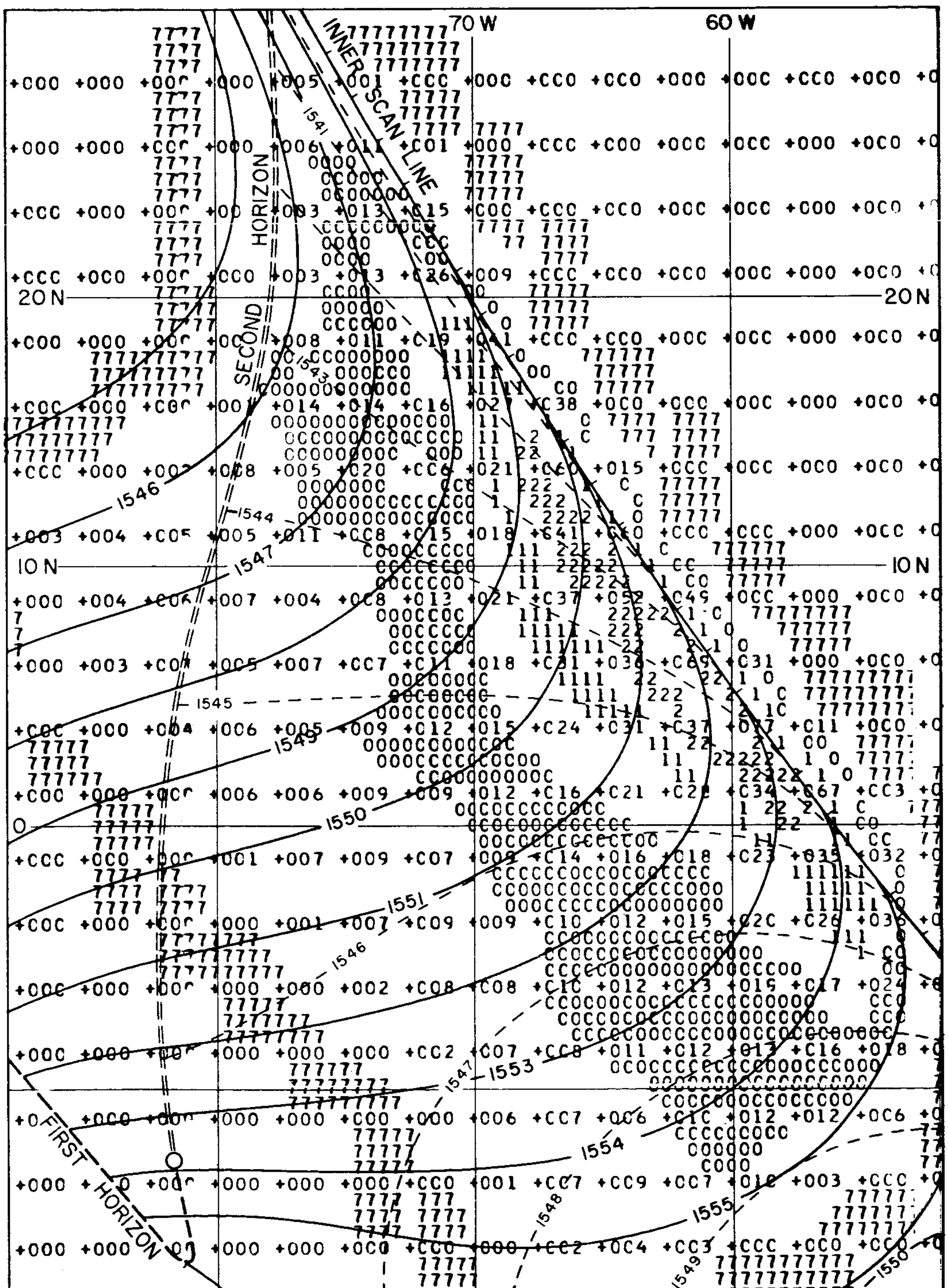
This chart produced by MSL represents the population of the data points within the 58° nadir-angle limit.



APPENDIX

Ae POPULATION MAP, TIROS III, ORBIT 132

Both initial scan lines (solid lines) and secondary scan lines (broken lines) are superimposed upon the population map. Notice the high population near the inner scan boundary. The grid points just outside the boundary indicate high population counts due to the fact that the square boxes include the high population areas to the west of the scan boundary.



APPENDIX

Af POPULATION MAP, TIROS III, ORBIT 132

The scan boundary and the 58° nadir-angle limit superimposed upon the population map. Within the shaded area the data points belonging to both initial and secondary scans are counted as the population.